DECEMBER 1961
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Materials Research & Standards

AMERICAN SOCIETY FOR TESTING AND MATERIALS

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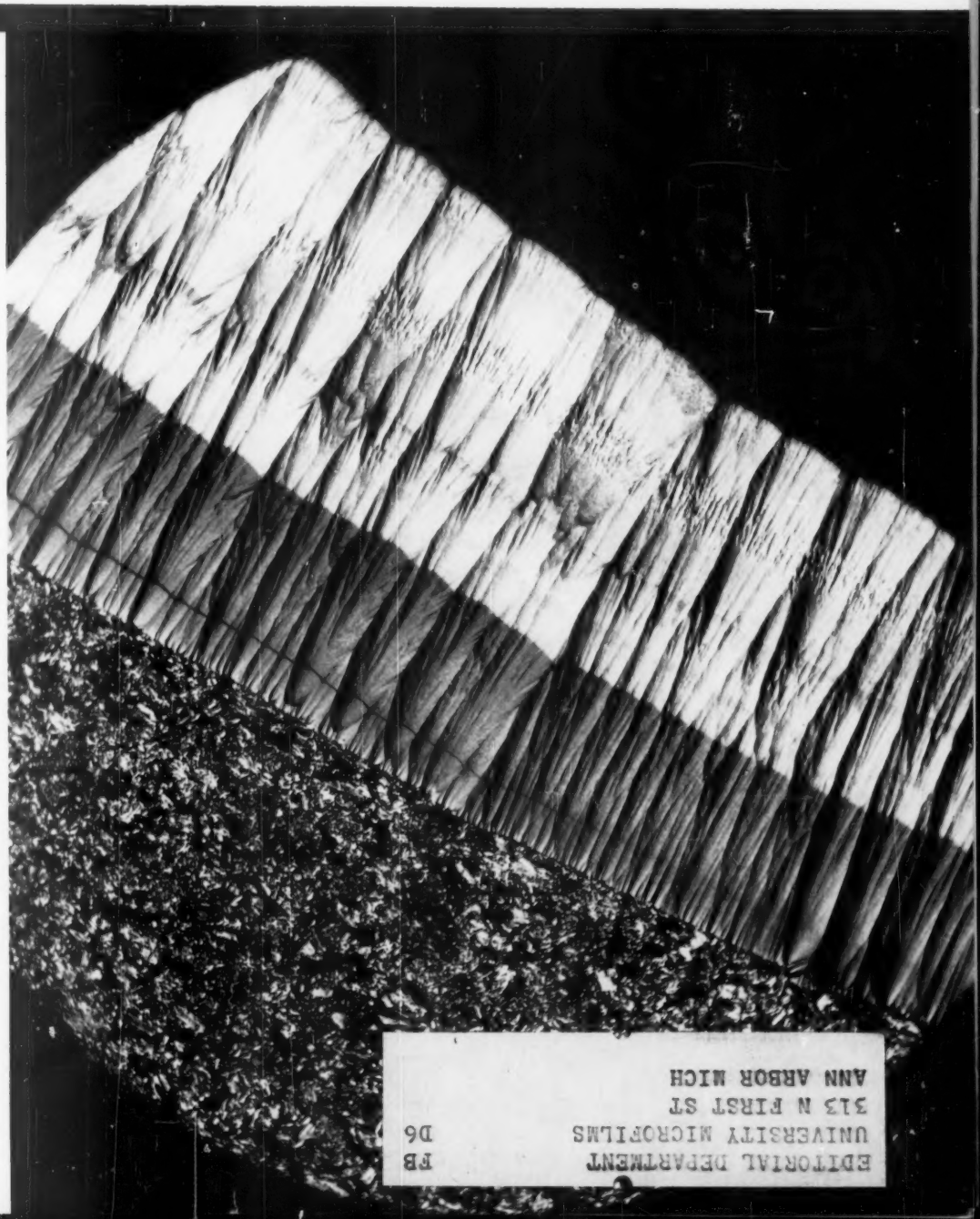

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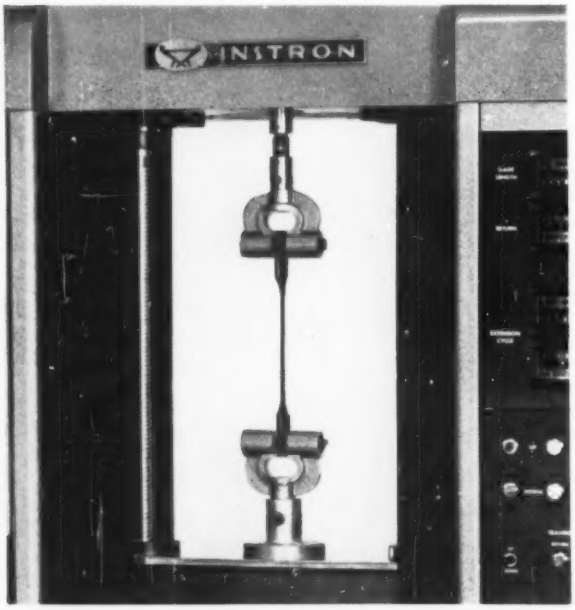
$$ST_0/RTa_T = \int_{-\infty}^{\infty} M(\tau)\tau(1-e^{-\tau/Rta_T})\,d\ln\tau$$

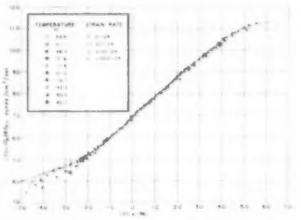
The above formula, recently developed with an assist from Instron, enables rheologists to predict, with accuracy, the complex linear viscoelastic properties of certain polymers from simple stress-strain data. For example, it is possible to calculate stress-relaxation modulus from a simple tension test.

.....OR HOW TO PREDICT VISCOELASTIC BEHAVIOR FROM SIMPLE STRESS-STRAIN DATA

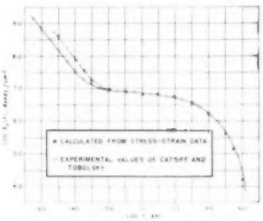
The equation itself was none of our doing, of course. (For details on how the equation was developed, see below.) But we can point with pride to the fact that the universal tester which furnished the stress-strain criteria used in the study of the applicability of the new formula to polymeric material bears the Instron name.



The Instron's servo-controlled testing speed was extremely useful in the test. The constant crosshead speed imposed constant strain rate in the sample for elongations up to 150%. Unique extension-recording system of the Instron made it possible to measure strain accurately without extensometers.



Stress-strain data reduced to unit strain rate at 298°K.



Stress-relaxation modulus derived from stress-strain data compared with experimental data of Catsiff and Tobolsky.

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$$ST_0/RTa_T = \int_{-\infty}^{\infty} M(\tau)\tau(1-e^{-\tau/Rta_T})\,d\ln\tau$$

How the formula was used: Samples of synthetic, non-crossed linked rubber were tested at 10 temperatures between −54° and 85°C and at constant strain rates between 0.014 and 0.1C4 x 10^{-3} sec^{-1} on the Instron Universal Tester. Stress-strain data were reduced mathematically to unit strain rate to yield a single curve for each temperature. Curves were then superposed to determine temperature dependence of viscosity, then all data up to 100% elongation were reduced to a single stress-strain curve accurately predicting viscoelastic behavior over nine decades of reduced time. It was shown that stress-relaxation modulus could be calculated satisfactorily from the reduced stress-strain curve.

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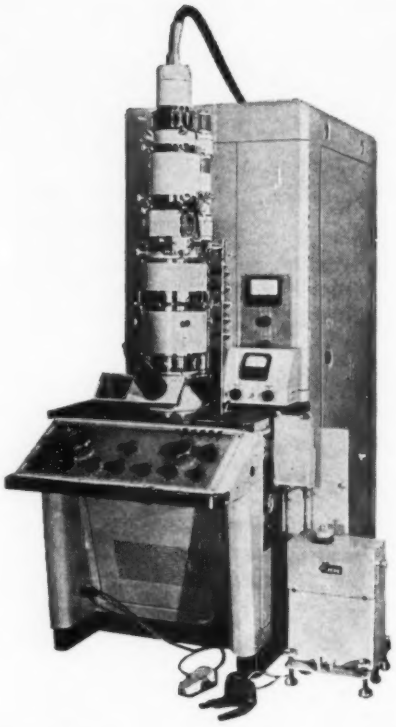

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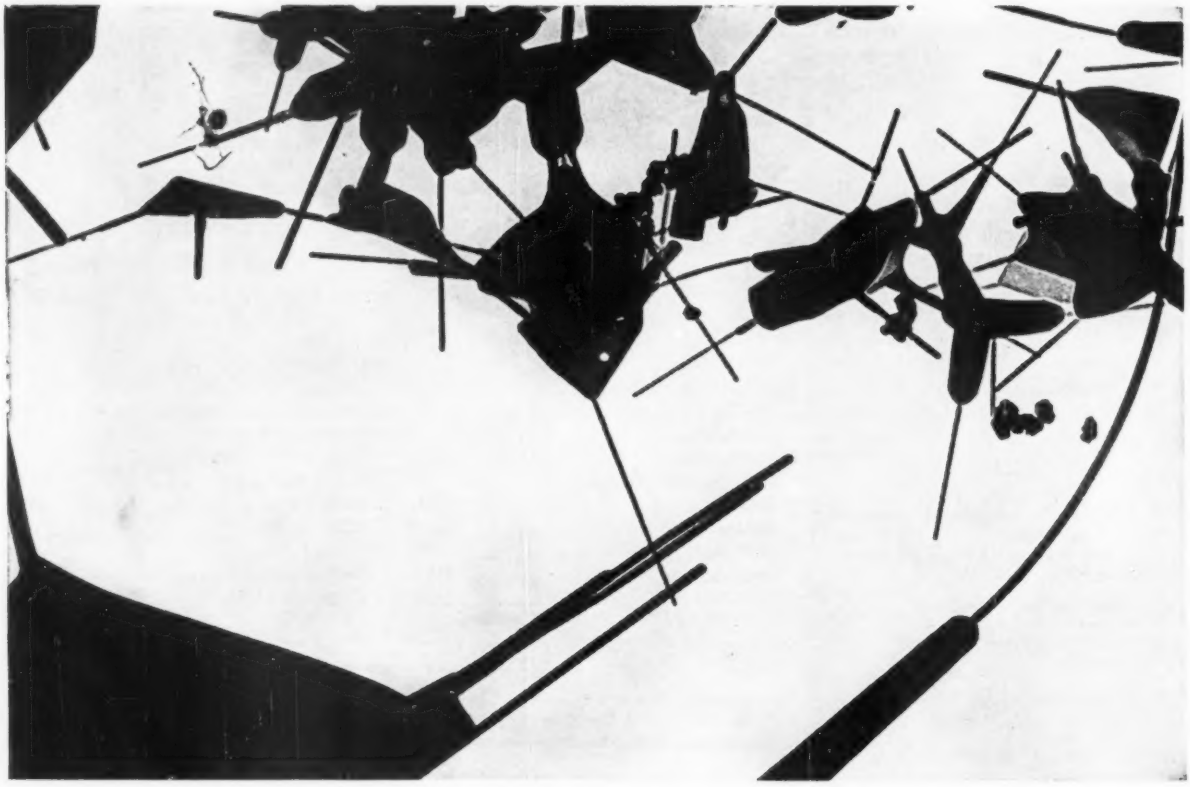

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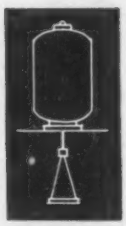

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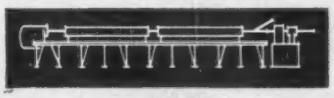

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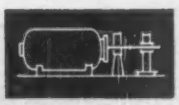

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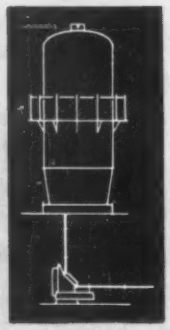

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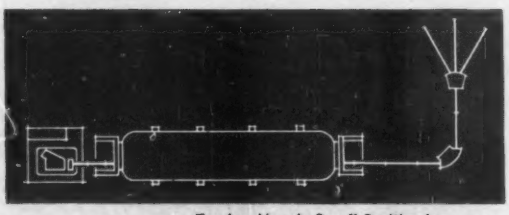

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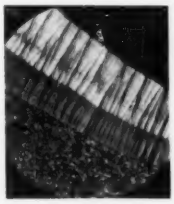

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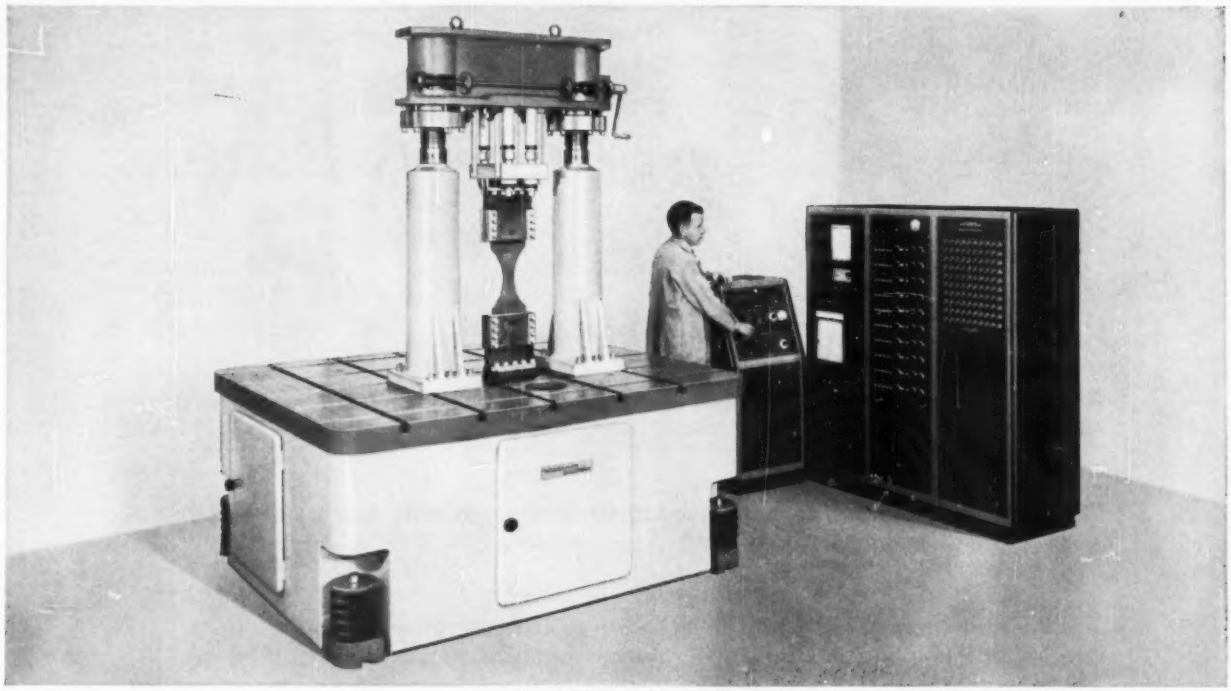

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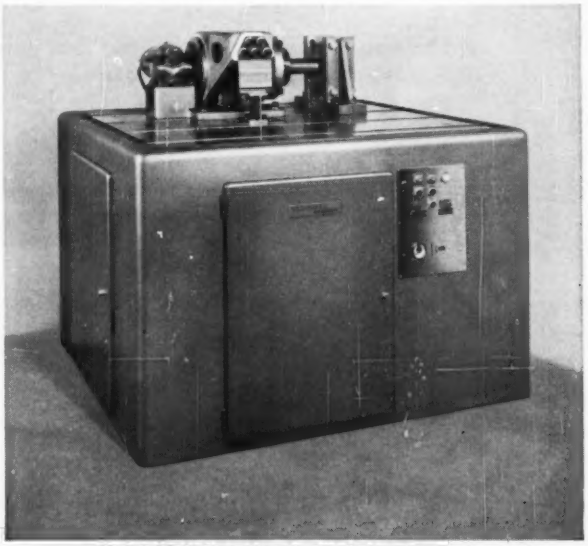

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Materials
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Volume 1, Number 12, December, 1961

On Tyrants and Tyrannies

THE PRESENT leaders of the USSR are peace-loving men. Their dearest wish is to see peace established throughout the world. Toward the realization of this goal they are devoting their fullest energies.

How does the normal, intelligent, level-headed individual (you and I) react to these words? Either we are struck by the comedy, and laugh, or we are outraged by the affront, and curse. But there is a third possibility. It is an easy matter to make these statements completely acceptable to the Western mind simply by giving the following definition: "Peace is that state of harmony that will exist among all nations once they have agreed to subject themselves to the will of the Soviet Union." At once, everything comes clear.

The world has never lacked tyrannies for men to struggle against. The one in all our minds in this second half of the twentieth century is, of course, the Communist tyranny. But one that has been with us far, far longer is the tyranny of words, which is the phrase used by Stuart Chase in 1938 to describe the great barrier to understanding that is built into our language because of the equivocal meanings of words.

Communist tyrants are especially adept at putting this older tyranny to work for them. Witness their diabolical use of the word "peace." Witness the spawning of "People's Republics" governed by tyrants for tyrants, and the "free youth" movements that flourish in the Red dungeon states. The Communists, of course, have no monopoly on these tricks, although they are exceptionally skilled in their use. Others tend to twist the meanings of words to their own ends. And all of us use words whose meanings are ill-defined.

All, perhaps, but the scientists. In science, certainly, one finds a passion for definition of terms. One knows what one means by "heat," or "hydrogen," or "logarithm." Classifying and defining are, in fact, at the root of all science. As J. B. S. Haldane wrote, "Mechanics became a science when physicists had decided what they meant by such words as weight, velocity, and force, *but not till then.*"

The cool, objective sureness of the scientist with his words stands him in good stead when he speaks with other scientists. But in the hurly-burly of the outside world, his words sometimes seem inappropriate. Take, for example, the present anguished turning to the scientist to find how serious is the poison now falling upon us from the sky. What injuries are being done to the yet unborn? There is, of course, no clear answer. Some scientists have been quoted as saying that the present levels of radioactivity will cause no "significant" damage. Now, in many contexts, the word "significant" has a legitimate statistical meaning. But in the context of human tragedy it is misused. In a population of 180 million, the birth of one child blinded or otherwise malformed through human folly is significant. It is as much an outrage as were the corpses piled like cordwood at Belsen and Dachau. Statistics are useful in the study of rabbits; they are inapplicable in the area of human misery.

A. Q. M.

Sinusoidal-Strain Dynamic Testing of Rubber Products*

By A. R. PAYNE

A sinusoidal-strain dynamic tester was recently developed for testing rubber products. Brief descriptions of two models of this tester are given, and some typical results are quoted.

THIS PAPER is concerned with methods for evaluating the dynamic modulus and hysteresis of rubber under a wide range of conditions. The original machine in use at the Rubber and Plastics Research Assn. (RAPRA), and then its commercially available counterpart, the Wallace electronic sinusoidal-strain dynamic tester, are described. Some typical results obtained with the first machine, but obtainable with either, are given.

Properties of Rubber

Rubber is not a unique chemical material, but a state of matter involving long-chain molecules characterized by freedom of rotation at single bonds between atoms in the chain. This leads to a noncrystalline, tangled, three-dimensional network, cross-linked at comparatively infrequent intervals along the polymer chain. Under the application of stress, the network extends by rotation of the bonds so that configurational or "entropy" changes occur. This explains the high extensibility of rubber, as opposed to straining by bending or extension of interatomic bonds, as is the case with metals. The elastic properties of some polymers can be approximately deduced from the kinetic theory of elasticity.

The rotation and movement of the molecules past each other involve energy losses, so that rubbers are not completely elastic and must be regarded as possessing simultaneously elastic and viscous properties. This leads to an analogy being made with models comprised of springs and dashpots. Analysis of the behavior of simple models under applied sinusoidal strain may be made by application of analogous a-c network theories. This enables the complex modulus, E^*, to be analyzed into two components, E', the in-phase elastic modulus, and E'' the loss modulus due to the out-of-phase viscous component. These properties can be added vectorially as:

$$E^* = E' + iE'' \quad \ldots\ldots\ldots (1)$$

and,

$$\tan \delta = E''/E'$$

where:

δ = loss angle, and
i = 90-deg operator.

These two quantities or the corresponding shear moduli, G' and G'', are therefore the two basic properties it is required to measure. An alternative, of course, is to measure the ratio of the out-of-phase and in-phase moduli, that is, $\tan \delta$, or else the loss angle, δ, itself. The testing machines discussed can measure all these parameters.

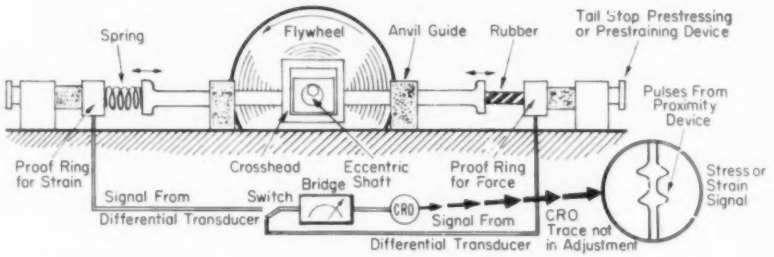

Fig. 1.—RAPRA sinusoidal strain machine; forced vibration, nonresonant type.

The RAPRA Machine

In the machine designed at RAPRA (Fig. 1), an eccentric shaft rotates in a sliding block which moves a crosshead to which two anvils are symmetrically fixed. This mechanism ensures that the displacement of the anvil is sinusoidal, while the setting of the eccentric controls the throw of the anvils. Inertia is given to the system by two flywheels fixed on the shaft, the smaller being sufficient to provide the required momentum at high speeds, while at lower speeds momentum can be added by attaching the larger flywheel to it. The rubber specimen is mounted between one of the moving anvils and a stationary anvil. A more detailed description of this construction has been published (**1–4**).[1]

Force Measurement

Force is measured by a metal proof ring, the deformation of which is measured by a differential transducer (**5, 6**), several makes of which are easily available. The proof ring is made by cutting a slit and two cylindrical holes in a solid steel block. Its sensitivity is determined mainly by the thickness of the

NOTE—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author or authors. Address all communications to ASTM Headquarters, 1916 Race St., Philadelphia 3, Pa.

* Presented at the Sixty-third Annual Meeting of the Society, Atlantic City, N. J., June 26–July 1, 1960.

[1] The boldface numbers in parentheses refer to the list of references appended to this paper.

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remaining wall. The transducer probe bears on one face of the slit.

A transducer that can detect and measure displacements from 0.1 μ to 1 mm is connected through a bridge circuit to the Y plates of an oscilloscope, the signal being proportional to the strain (and hence, force) developed in the proof ring. The over-all force amplitude is deduced from the amplitude of the electrical signal on the tube of the oscilloscope and can be measured directly by conventional means using the oscilloscope as a vacuum-tube voltmeter.

Phase-Angle Measurement

The device for measuring the phase angle, δ, consists of a rotating fabric-reinforced polyfluoride resin disk (Tufnol) in the periphery of which are two small metal inserts 180 deg apart (M, Fig. 2(a)). The disk is attached to the shaft of the machine. A capacitance probe moves over a protractor scale, keeping close to the periphery of the disk. When the disk is revolving, as each insert passes the probe, there is a rapid change of capacitance between the insert and the probe, and the signals, which are in the form of pulses, are fed to the X plates of the oscilloscope.

With the time base (X direction) inoperative, the pulses from the proximity meter deflect the signal from the stress-measuring device twice per cycle of the rotating disk. The type of signal obtained on the tube face is shown in Fig. 2(b). By rotating the position of the probe the two pulses can be brought into coincidence. The accuracy of the coincidence can be increased by amplifying the stress signal so that only a small fraction of the over-all stress trace appears on the tube face. When coincidence is obtained the pulses coincide with the zero point of the stress signal. The position of the probe with respect to the scale is then read.

A metal spring is placed between the other driven anvil and a second stationary anvil and a similar proof ring measures the force due to the sinusoidal strain imposed on it; this force signal is equivalent to the strain signal, since there is no phase lag between force and strain in the spring. When the switch (Fig. 1) is thrown, this "strain" signal from the spring replaces the "stress" signal described in the previous paragraph, and setting of the probe is readjusted for pulse coincidence. The readjusted setting then coincides with the zero point of the strain signal. The difference between the settings of the probe to give coincidence positions for stress and strain, respectively, is a direct measure of the phase-angle in degrees. The accuracy of phase-angle-measurement depends mainly on the radius of the disk; with the 4-in. disk used on the machine at RAPRA the angle can be measured to less than $\frac{1}{2}$ deg.

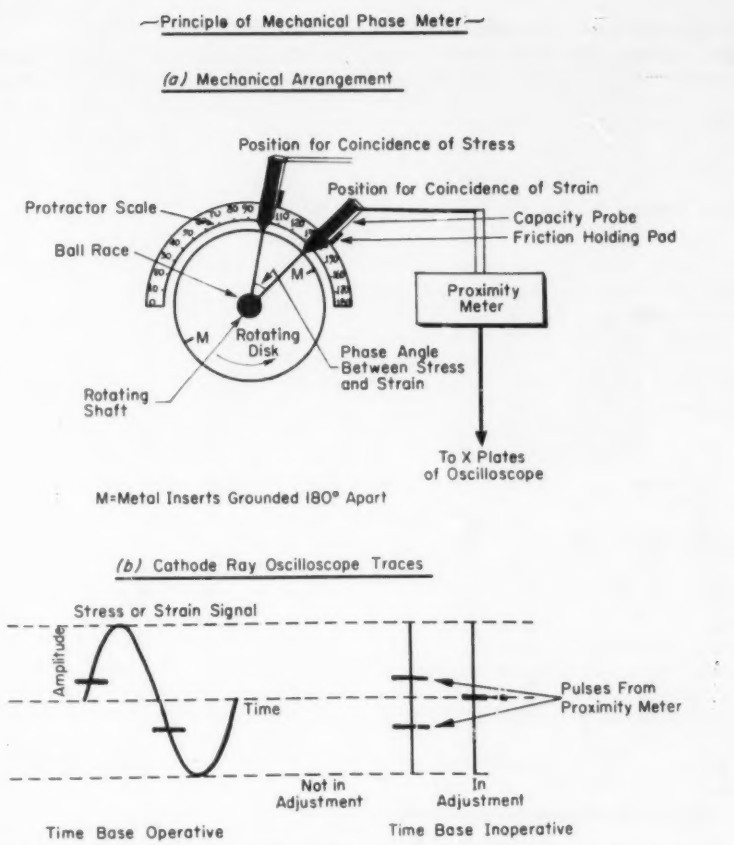


Fig. 2.—RAPRA sinusoidal strain machine; mechanical phase-measuring device.

With this apparatus the operator has thus only to measure, (1) the over-all stress-signal amplitude (devices to measure this directly are incorporated in the oscilloscope), and (2) the difference in setting of the probe to give the phase angle. These two methods allow the in-phase and out-of-phase modulus components to be calculated, since the strain amplitude is known from the setting of the eccentric and can also be measured directly by a dial gage.

At very low frequencies (<0.01 cps) this mechanical phase-measuring device is not practical, but the stress and strain signals are then slow enough to be accurately traced out directly on a moving pen recorder and the traces compared.

Range of Test Conditions

In this machine the amplitude of the dynamic cycles can be varied from 0.001 to 0.25 in. Still lower strains are obtainable by methods to be discussed later. The frequency range used is from 0.0001 to 30 cps. A range of proof rings that measure forces from 0.01

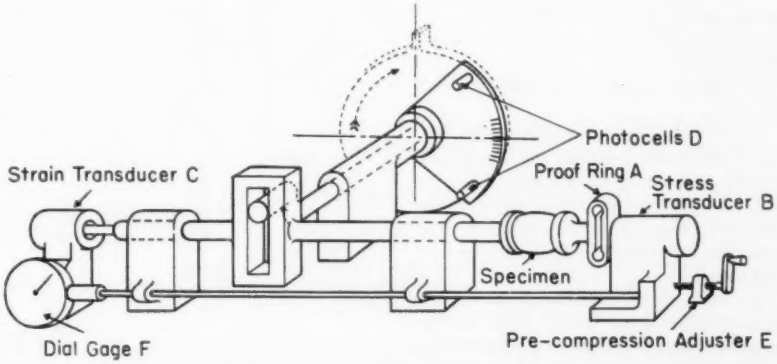


Fig. 3.—Wallace electronic dynamic tester; schematic drawing of mechanical assembly.

lb to several tons is available, thus allowing a wide range of specimens to be tested. Anvils suitable for tests in shear, compression, or combinations of these, or tension or torsion, are available, and the specimen temperatures can be controlled between −70 and 200 C.

The Wallace Machine

The Wallace machine (7), a commercially developed version of the RAPRA machine, is illustrated diagrammatically in Fig. 3. A revolving eccentric provides the sinusoidal displacement cycle, and the specimen is mounted between one fixed and one reciprocating face or grip.

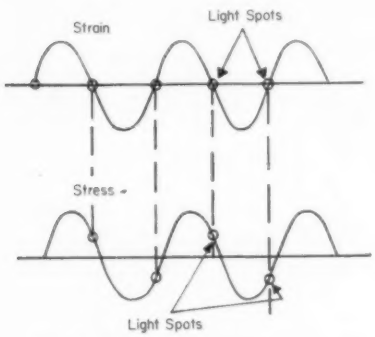


Fig. 4.—Phase-angle measurement.

Stress or load is measured by deflection of the proof ring, *A*, to which is attached a displacement transducer, *B*. The output from this transducer is amplified and compensated for the cross-sectional area of the specimen if the result is required in terms of applied stress. Whereas in the laboratory model the proof ring is changed when a different range of stress is needed, this instrument uses one proof ring throughout the stress range and compensation is made for the loss of dynamic strain amplitude due to deflection of the ring.

Strain is measured directly by transducer *C*. Mean strain is applied by the handwheel, *E*, and is measured by the dial micrometer gage, *F*. This arrangement compensates for the loss of mean strain due to the static deffection of the proof ring, *A*. The parameters measured on this machine are:

1. Mean strain—indicated on dial gage, *F*,
2. Mean stress—measured directly by a calibrated electronic control which cancels out this component,
3. Displacement frequency—measured from the parameters or more conveniently from a recorder chart speed or generator,
4. Peak dynamic strain; peak dynamic stress—Read directly from meters or alternatively from the parameters using a calibrated oscillograph, and
5. Phase angle.

Phase-Angle Measurement

Phase angle in this machine is measured by using a "spotting" technique, whereby light spots are made to appear on both oscilloscope traces. These spots are obtained from impulses received as a result of a peg on the flywheel passing between two photocells and two light sources. The two photocells can be rotated as an assembly, *D*, about the axis of the flywheel in a controlled manner. This movement causes the light spots to move along each trace.

The photocell assembly is moved until the two light spots on one trace lie in a horizontal straight line (Figure 4). A protractor scale is set to read zero. The photocell assembly is moved again until the light spots on the second trace lie in a horizontal straight line. The protractor now reads phase angle. Alter-

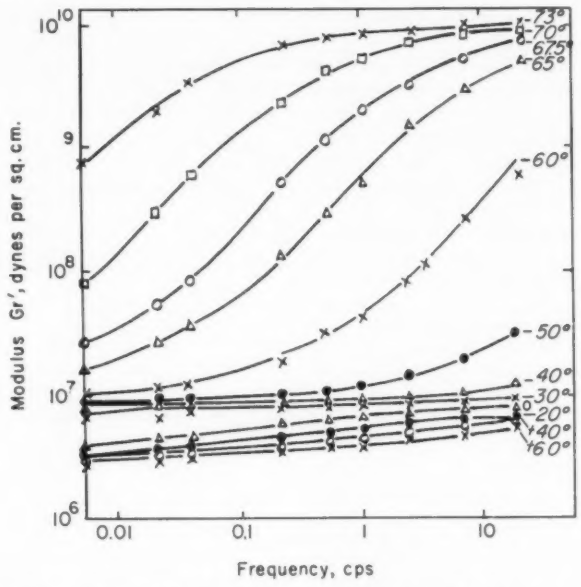


Fig. 5.—Reduced in-phase modulus, G', for unvulcanized natural rubber; variation with frequency at various temperatures, deg Cent.

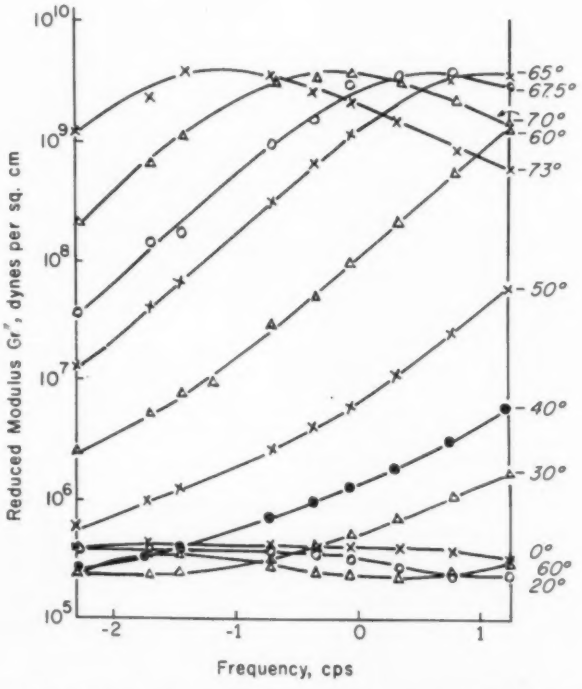


Fig. 6.—Reduced out-of-phase modulus, G'', for unvulcanized natural rubber; variation with frequency at various temperatures, deg Cent.

natively, if the time base is cancelled from the oscilloscope the traces appear in vertical lines and the measurement is similar to that described earlier.

Range of Test Conditions

Test conditions are broadly similar to those in the RAPRA machine except that two temperature control chambers are provided, one for subnormal temperatures and the other for supernormal temperatures. These chambers are designed to fit neatly around the specimen so that only the specimen is brought to the required temperature. Subzero temperatures down to −100 C are achieved by evaporating liquid nitrogen.

Typical Results

It is convenient to consider the elastic and viscous stress components as corresponding to two separate moduli, so that the effective elastic modulus is really a complex modulus G^* (E^*, if we choose the extension modulus) made up of a truly elastic or in-phase component, G', and a viscous or out-of-phase component, G''. The relationship between these is represented by the vector addition in Eq 1.

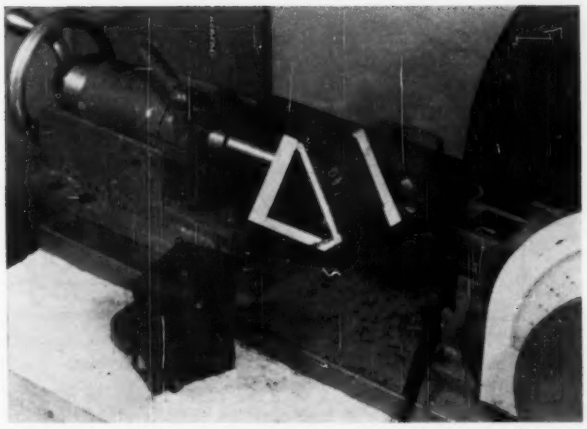


Fig. 7.—RAPRA sinusoidal strain machine being used to test an engine mounting.

Figures 5 and 6 show respectively, the values of G' and G'', reduced to a reference temperature by the Ferry transforms (8). These curves are quite typical of unvulcanized and vulcanized rubber, rubber-cork mixtures, gelatins, etc., showing how the results change from that of a rubbery material at high temperatures to that of a glass-like material at low temperatures.

Product Testing

Figure 7 is a photograph of the instrument at RAPRA being used to evaluate the dynamic properties of an engine mounting. The rubber unit is being dynamically stressed under a constant mean stress equal to that produced by the weight of the engine, and is set at an angle to the anvils to simulate the normal setup in service. Tests were carried out over a frequency and temperature range as well as at various mean stresses and strains.

Effect of Amplitude

The dynamic moduli of rubbers which contain carbon blacks or other fillers change markedly with amplitude. This change is thixotropic in nature, and earlier work on the machine showed that there are large changes in dynamic modulus and phase angle at amplitudes occurring in service. For these studies the laboratory machine was adapted to cover a wide strain range.

The machine was designed originally to measure stress from a known im-

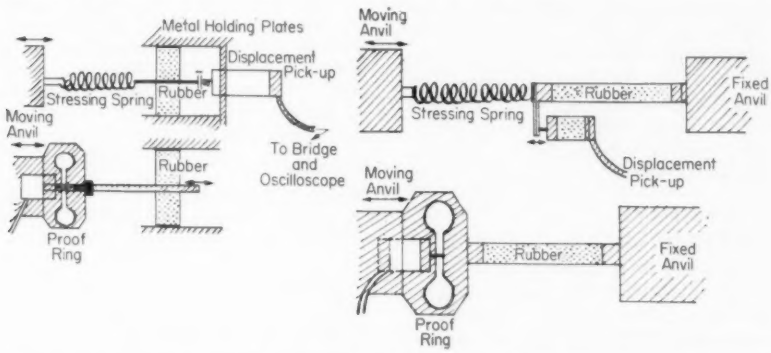


Fig. 8.—Schematic drawing of the two jigs used to cover a wide strain range in shear.

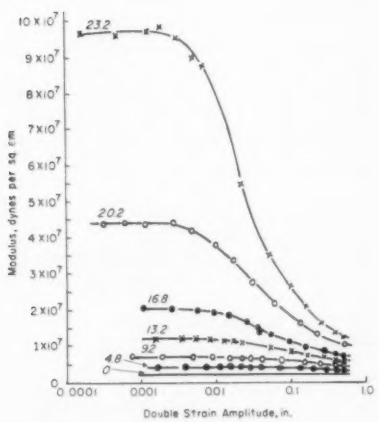


Fig. 9.—Variation of the dynamic shear modulus, G^*, with the strain amplitude of testing for butyl rubber containing various volumes of high-abrasion furnace (HAF) black. Tested at 1 cps.

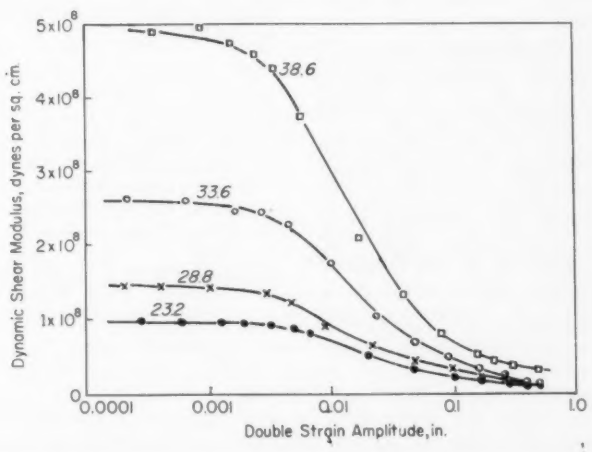


Fig. 10.—Variation of the dynamic shear modulus, G^*, with the strain amplitude of testing for butyl rubber containing various volumes of high-abrasion furnace (HAF) black. Tested at 1 cps.

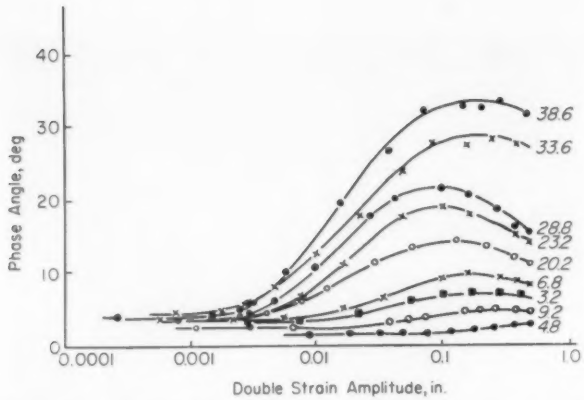
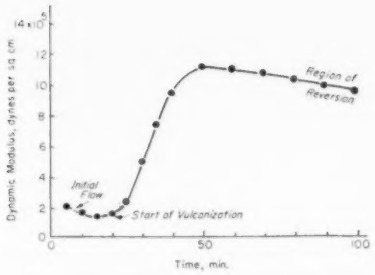


Fig. 11.—Variation of the phase angle, δ, with the strain amplitude of testing for butyl rubber containing various volumes of high-abrasion furnace (HAF) black. Tested at 1 cps.



The curve illustrates the initial period of flow while the rubber is warming up, the onset and completion of vulcanization, and the onset of reversion.

Fig. 12.—Variation of the dynamic shear modulus, G^*, with times of heating at 150 C of a pure gum natural rubber compound. Tested at 1 cps.

posed strain with a maximum displacement of the moving anvils of ± 1.25 cm. Lower amplitudes ($<200\ \mu$) were limited by the tolerances in the bearings, but, by using a spring between the moving anvil and the rubber specimen, a large movement of the anvil was reduced to a considerably smaller movement on the rubber, this movement being measured directly by a displacement transducer.

Schematic drawings of the jig used to shear two rubber cylinders are shown in Fig. 8.

Figure 9 shows the complex shear modulus plotted against the double strain amplitude for butyl vulcanizates containing up to 23 per cent of high-abrasion furnace black (HAF) as a filler, and Fig. 10 continues the plot up to 38.6 per cent of HAF by volume. Figure 11 shows the phase angle plotted against the double strain amplitude for the same vulcanizates. Again, there are large changes associated with the strain amplitude, and these results shown are quite typical of the effect of strain amplitude on the dynamic properties of rubberlike materials containing fillers.

Effect of Cure

The machine can be used to follow the progress of cure on rubbers that are being stressed in shear. This requires two small specimens of rubber to be loaded in shear, on either side of the reciprocating plate (as in Fig. 8) and the dynamic stiffness to be measured at the temperature of test, which is set at the curing temperature. Figure 12 shows a typical set of data obtained when a natural rubber compound is cured. There are, however, simpler, even if not so accurate, instruments available for this purpose.

Applications

The testing machines described in this paper are used to determine the dynamic properties of rubber specimens or complete rubber engineering assemblies under wide ranges of conditions. The effect of shape, frequency, temperature, and strain or stress amplitude under different stresses or straining conditions can be determined. The instruments can be used to follow the progress of cure, and can also be used to follow the dynamic properties of other materials such as rubber-cork mixtures, gelatins, and bitumens, besides both vulcanized and unvulcanized rubberlike materials.

Acknowledgments:

The author wishes to thank F. N. B. Bennett and A. R. More of H. W. Wallace and Co. and R. Batcheldor of Testing Machines Inc. for many helpful discussions and for permission to use the information in this paper on the Wallace electronic dynamic tester marketed by them, and for their help in the manufacture of the initial machines still in use at RAPRA.

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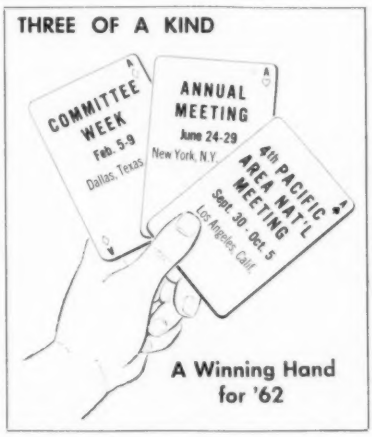

Detecting Outliers in Soil-Additive Strength Tests[1]

By H. T. DAVID, D. T. DAVIDSON, and C. A. O'FLAHERTY

A nomographic procedure is given which attempts to control the rate of unwarranted data disqualifications in a given experimental series. The procedure assumes a constant coefficient of variation for the series and involves the graphical computation of a disqualifying percentage corresponding to this coefficient of variation. An extension of the procedure allows for the assessment of the experimental series as a whole for reliability, homogeneity, and normality.

IN RECENT YEARS, various types of materials have been investigated for use as soil stabilizing agents in the construction of highways and airports. Since the properties and environmental conditions of soils vary so greatly from place to place, a stabilizing agent that is suitable for one type of soil may not be satisfactory for another. As a result, it is often desirable to evaluate several stabilizing agents under varying treatment conditions before deciding on one to be used with a given soil.

The unconfined compressive strength test is probably the most commonly used test in such soil stabilization investigations. The general procedure is, for one given test condition, to prepare and test several specimens (usually three), after which the average of the several strength values is reported. Because of the many variables involved, the total number of specimens may range from the hundreds to the thousands, depending upon the size and scope of the investigation.

Since such large numbers of specimens are involved, it is likely that some unconfined compressive strength results will be obtained that are, seemingly, not what they should be. The question then arises whether these unusual observations are the result of expected normal experimental variation or whether they are due to an experimental or material aberration and should therefore be discarded. In cases where three specimens are prepared per test condition, a commonly used solution to this question is to discard any single measurement which deviates by more than 10 per cent from the average of all three measurements, as prescribed in ASTM Method C 109.[2] The average of the remaining two strength values is then reported.

It is felt that this blanket-type disqualifying percentage should be reappraised from a statistical point of view, since it is very possible that entirely valid strength values may attain this percentage simply by virtue of expected statistical fluctuation. Thus, many values may be unjustly disqualified. Since unjustly disqualified strength values carry information that is as valid as that carried by their supposedly more reliable neighbors, uncritical adherence to such a blanket-type disqualifying percentage causes needless loss of information. In addition, bias is introduced when any strength observation is wrongly discarded.

Proposed Disqualification Test

Step 1:

The statistical theory of this approach requires the existence and the estimation of a constant coefficient of variation (CV) for the entire series of observations. The CV of any observation equals the dispersion to which that observation is subject divided by the true value that the observation is supposed to estimate. It should be a constant for all the observations of a single investigation.

A simple nomographic procedure has been devised for establishing and estimating this constant CV.

Procedure for Establishing and Estimating the CV:

1(*a*). For each set of triplicate unconfined compressive strength values, com-

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[1] For another treatment of this subject, see ASTM Tentative Recommended Practice for Dealing with Outlying Observations (E 178–61 T), 1961 Book of ASTM Standards, Parts 3–11. When the ultimate interest is in estimating a mean, another point of view is offered by F. J. Anscombe, "Rejection of Outliers," *Technometrics*, Vol. 2, pp. 123 ff. (1960).

[2] ASTM Method of Test for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. Cube Specimens) (C 109–58), 1958 Book of ASTM Standards, Part 4.

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pute the ratio, r, of the range, R, of the three values to the average, $\bar{X}$, of the three values. The range is defined as the difference between the largest value and the smallest value of the three. Thus,

$$r = \frac{R}{\bar{X}} = \frac{X_{max} - X_{min}}{(X_1 + X_2 + X_3)/3} \quad (1)$$

1(*b*). Arrange all the r values so obtained in ascending order of magnitude. This can easily be done by plotting them on ordinary graph paper.

1(*c*). Choose approximately 30 well-spaced r values. For each selected r value, find the number, n, of other r values less than it, add $\frac{1}{2}$ to this number, and express the resulting figure as a percentage of the total number, N, of r values, that is, compute[3] $\frac{100(n + \frac{1}{2})}{N}$.

1(*d*). Plot each percentage against its corresponding r value on the nomograph, using scale A for the r values and scale B for the percentages.

1(*e*). Fit the 30 points so obtained with a straight line—hereafter called the CV line—passing through the origin. If the points lie reasonably close to the straight line, then constancy of the CV is established and the proposed test is applicable. (Questions of objective fit and closeness criteria are touched upon in the discussion.)

Outliers, if present, will tend to enlarge r unduly. This will cause the r pattern to form an arched rather than a straight line. In such cases, the points farthest from the origin should be excluded from the straight-line fit. A technical though perhaps impractical refinement here is to eliminate far points until the remaining replotted points form a satisfactory straight line.

The CV itself is estimated by the value on scale A at which the CV line attains a height of 24 on scale B.

It might be noted that prior workers in this general area have worked with the assumption of a constant CV (**1**).[4] In addition, a considerable number of experimental sets of data have been examined for constancy of the CV at the Iowa Engineering Experiment Station, and it has been found to hold in every case.

Step 2:

Upon the establishment and estimation of the constant CV, it is now possible to test for possible incorrect strength values. The procedure is as follows:

Procedure for disqualification of extreme strength values:

2(*a*). For each set of triplicate values compute the ratio U of the largest value X_{max} minus the average value $\bar{X}$ to the average value $\bar{X}$. Thus

$$U = \frac{X_{max} - \bar{X}}{\bar{X}} \quad \ldots\ldots\ldots (2)$$

2(*b*). For each set of triplicate values, compute the ratio V of the average value $\bar{X}$ minus the smallest value (X_{min}) to the average value $\bar{X}$. Thus

$$V = \frac{\bar{X} - X_{min}}{\bar{X}} \quad \ldots\ldots\ldots (3)$$

2(*c*). Enter scale D at the total number of triplicate sets. Through this point draw a horizontal line until it intersects the CV line through the origin. Read on scale A the value t of the abscissa of this intersection point.

2(*d*). For both U and V, t is the critical value. Any triplicate whose U exceeds t should have its X_{max} discarded; similarly any triplicate whose V exceeds t should have its X_{min} discarded. In other words, the t value, when expressed as a percentage, is the disqualifying percentage for the investigation at hand.

It must be realized that, although the suggested procedure controls the rate of wrong disqualifications, it cannot reduce this rate to zero. It is therefore possible that valid observations may be disqualified. Similarly, a certain number of outliers will not be detected. Wrong disqualifications can occur either when all three members of the triplicate set are subject only to ordinary experimental variation or possibly because the two remaining values are, in fact, the illegitimate ones. The investigator seeking additional controls for errors of this type may wish to crosscheck the disqualifications suggested by the present procedure against the disqualifications suggested by the magnitude of the corresponding residuals from fitted regression functions (**2**). This crosscheck is not further discussed in this paper.

Where the crosscheck is not used, it is recommended that, if one observation is disqualified, the middle observation of the original three then be reported. If it should happen that both U and V are extreme for one triplicate set, the entire triplicate set should then be discarded.

Step 3:

In some cases it may be of interest to check on the reliability of the investigation as a whole. This may be necessary for many reasons, such as suspected unreliability of the operator, nonnormality, or nonhomogeneity of the material under test.

Criterion for the reliability of the entire investigation:

3(*a*). Arrange all the U values in ascending order of magnitude. This is most easily done by plotting them on ordinary graph paper.

3(*b*). Select approximately 30 well-spaced U values. For each selected U value, find the number of other U values that are less than the selected U value, add $\frac{1}{2}$ to this number, and express the resulting figure as a percentage of the total number of U values.

3(*c*). Using the nomograph, plot on scale E each percentage obtained in 3(*b*) against its corresponding U value on scale A.

3(*d*). Fit the points so obtained by a straight line—hereafter called the U line—through the origin.

3(*e*). Repeat steps 3(*a*), (*b*), (*c*), and (*d*) for V to obtain a V line.

The extent of noncoincidence of the three lines obtained in 1(*d*), 3(*d*), and 3(*e*), and the extent to which the three sets of points fail to be fitted by the CV line—indeed the actual shape of the sets themselves—will provide clues concerning series-wide unreliability, nonhomogeneity, and non-normality. For example, nonhomogeneity, in the sense of more than one underlying coefficient of variation, will cause the three sets to form similar S-shaped curves, arching first downward then upward, the first arch typically being the more pronounced. This effect is similar to that arising under "inadvertent plot splitting" in half-normal plot analyses (**3**) and is due to similar causes. Again, certain types of operator fabrication will manifest themselves in distinctive patterns.

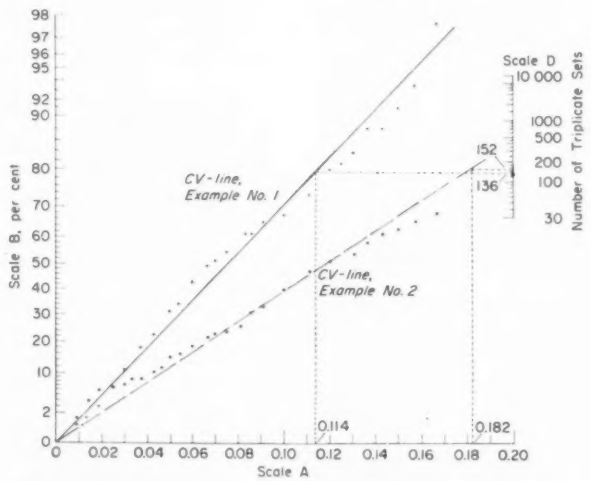


Fig. 1.—Nomographic computation of disqualifying critical values.

[3] Addition of $\frac{1}{2}$ to n is not necessary for values of N greater than 150.

[4] The boldface numbers in parentheses refer to the list of references appended to this paper.

For example, fabricating a triplicate from a single determination by adding and subtracting fixed proportions of the single determination will cause a vertical discontinuity to appear in all three plots. On the other hand, fabricating a triplicate from a pair of determinations by interpolation will cause a configuration similar to but typically less extreme than that arising under nonhomogeneity.

Should serious series-wide non-normality be uncovered, the clash of non-normal data with normal theory should, as a rule, be resolvable in favor of the theory. In other words, non-normality of data often will have an identifiable and removable cause.

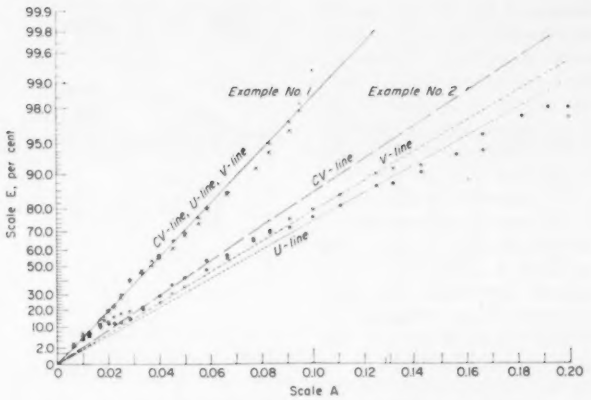


Fig. 2.—Nomographic assessment of series reliability.

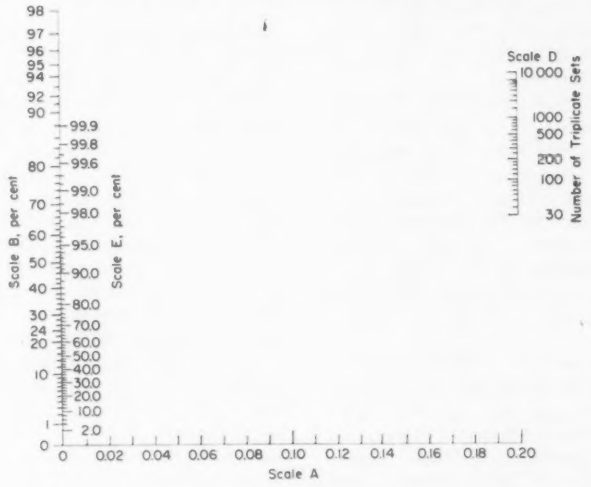


Fig. 3.—Outlier paper.

Examples

The proposed technique will now be applied to two series of triplicate determinations. The first example involves 134 triplicate sets of unconfined compressive strength determinations of soil-calcium lignosulfonate-aluminum sulfate specimens (**4**). The second example involves 152 triplicate sets of unconfined compressive strength determinations of soil-lime-sodium silicate specimens (**5**).

As shown in Fig. 1, the estimated CV for the first example is 0.048, and the critical t is 0.114, corresponding to a disqualifying percentage of 11.4. None of the 134 triplets were disqualified by this criterion. As shown in Fig. 2, the CV line, U line, and V line coincide, with the U points and V points falling close to this joint line. All indications therefore point to the fact that this investigator was in thorough control of his experiment.

The estimated CV for the second example is approximately 0.074, indicating a degree of experimental precision lower than that of the first example. This lower precision probably does not represent an operator effect but is probably due to the well-known rapid gel-forming ability of sodium silicate. Low precision does not by itself constitute evidence of experimental inefficiency but, as is likely in the present case, can be the result of inherent material properties. The critical t-value for this example is approximately 0.182, corresponding to a disqualifying percentage of 18.2. From the reliability check plotted in Fig. 2, the CV line, U line, and V line are seen not to coincide. Moreover, the U points and V points do not lie close to their respective lines. The tendency to downward curvature exhibited by both the U points and V points suggests the possibility of nonhomogeneity of experimental material.

It is important to note that the critical percentage of 11.4 for the first experimental series is near the blanket percentage of 10 per cent, which parenthetically, is exceeded by 3 triplicate sets of this series. This 10 per cent is also exceeded by 38 triplicates of the second series. Use of the critical percentage "tailor-made" to inherent experimental variability thus leads to a reduction in the number of disqualifications in the case of both experimental series. These are, namely, 0 versus 3 for the first example and 18 versus 38 for the second example.

Note that the two types of nomographic computations shown in Figs. 1 and 2 can be performed on a single nomograph. A sample of such a nomograph, called "outlier paper," is given in Fig. 3.

Discussion

It is planned to discuss the details underlying the proposed procedure in a separate technical publication. However, it seems appropriate to give a brief theoretical discussion here.

The outlier paper of Fig. 3 is based upon the following facts.

1. The ratio r/CV has approximately the distribution of the range of three unit normal deviates (**7**), and U/CV and V/CV have approximately the distribution of the largest minus the average of three unit normal deviates (**10**). Verifying computations indicate that these approximations are sufficiently exact as long as the coefficient of variation is less than 0.15. Scales A and B represent inverse probability transformations corresponding to the above two functions of unit normal variables. The linearizing property of inverse probability transformations has been exploited before (**3**).

2. In view of the above, the cumulative distribution functions (CDF) for r, U, and V are straight lines through the origin and have slope of $1/CV$ when plotted on the outlier paper. This enables the CV line, which is, in fact, the estimated cumulative distribution of r, to yield critical values for U and V, that is, to be used as if it were, in fact, the cumulative distribution function of U and V.

It is important to note that, ideally,

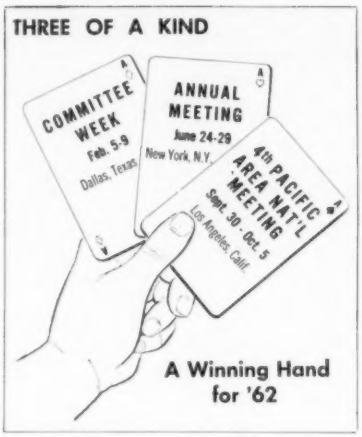
the construction of the CV line should be based on a statistic that is as insensitive as possible to outliers, whereas the disqualifying percentage derived from this CV line should be applied to statistics that are as sensitive as possible to outliers. Triplicate observations lend themselves only partially to these objectives if, as is assumed in this paper, both large and small outliers are involved. In view of this, the plot of the partially sensitive r values may show some downward curvature. In such cases it has already been recommended that the CV line should be fitted on the basis of the r points less likely to be contaminated by the outliers, that is, the r points closer to the origin.

In cases where it is known that only large outliers are present, an ideal insensitive statistic is the ratio of the difference to the mean of the middle and smallest observation.

With quadruple observations, almost complete insensitivity and sensitivity can be achieved even when both large and small outliers are present. A suitable insensitive statistic is the ratio of the difference to the average of the middle two observations, and a suitable sensitive statistic is the largest minus the average of the middle two, divided by the average of the middle two observations.

3. The method of obtaining the disqualifying percentage is based upon the "multiple-comparison" point of view that experimental series not containing outliers, regardless of their length, should suffer no disqualification with probability 0.5. It is realized that other points of view regarding the question of risk will lead to different D scales.

It is of interest to note the manner in which the critical disqualifying values for U and V depend upon the total number of triplicate sets and also upon the constant coefficient of variation. When the number of triplicate sets increases, the critical t value increases, which means that the critical U and V values also increase. This follows from the present point of view regarding risk and may be explained by the fact that, since a greater number of triplicates are involved, natural experimental variation is expected to produce greater numbers of extreme U and V values. The critical t value also increases with increasing CV. This is a reflection of the fact that the data are expected to be more erratic whenever the natural experimental error, of which the constant CV is a measure, is large.



Further theoretical considerations revolve about the manner of fitting the CV line and the manner of assessing the goodness-of-fit of the r, U, and V points to this line. As a rule, an eye fit will be adequate for the CV line, as other more sophisticated methods probably will not provide sufficiently greater accuracy to compensate for their greater computational complexities. A measure of goodness-of-fit is provided by the maximum vertical deviation, in units of percentage, of the 30 points from the straight line. This deviation may be approximately judged in terms of the known distribution of the maximum vertical discrepancy between a population CDF and its corresponding sample CDF (6). However, this distribution theory should be taken only as a rough guide since: (1) only 30 points of the sample CDF have been plotted, (2) the CDF to which this sample CDF is being compared is a fitted rather than a true CDF, and (3) whatever outliers are present are actually contributing to the discrepancy between the two CDF's. Alternatively, if one attempts to eliminate outliers by the refinement given in 1(e), maximum vertical deviations will arise that are considerably smaller than those expected according to the standard distribution theory.

Acknowledgments:

The authors thank H. O. Hartley and J. J. Moder for helpful contributions to this investigation. Appreciation is also due to R. Altenberger and M. Grimes for high-speed computational assistance.

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Appreciation is due to the Statistical Laboratory of Iowa State University for making available professional and high-speed computer time.

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Improvement in Fatigue Resistance of Aluminum Alloys by Surface Cold-Working

By G. A. BUTZ and J. O. LYST

These tests show that surface rolling and peening can have a large effect on fatigue resistance of aluminum alloys. The amount of this effect depends on the material and the stress situation, being greatest where sharp stress gradients, such as are associated with notches, are present. Under axial stressing of smooth specimens there was very little, if any, effect. Service abuse was simulated in several ways, including notches, corrosion, and unfavorable residual stresses. In some situations, the indicated specimen strength was more than doubled. Proper prestressing specifications are shown to be related to the type of surface and stress distribution. Reductions in effect associated with heating after prestressing are briefly explored.

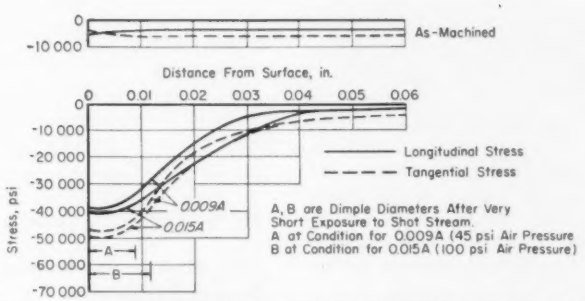
IT HAS BEEN known for many years that the fatigue resistance of metal parts can be improved by surface cold working. However, it has only been in recent years that the procedure has been widely used. Today, it is used to some degree in a very large proportion of the cars, trucks, and airplanes produced in this country, and has found wide application in many other fields. The tests reported here were not conceived as an integrated attempt to investigate thoroughly all aspects of surface cold working, but rather were a series of programs designed to answer specific questions.

Mechanical surface cold working is accomplished by local plastic yielding of the surface layers. The most common methods are shot peening and surface rolling. In these operations, by virtue of a localized pressure, the surface metal is stressed beyond its elastic limit. When the pressure is removed, the surface layers retain part of the deformation experienced under pressure. Subsurface material which has not exceeded the elastic limit attempts to force the surface elements to return to their original length, thereby inducing a surface residual stress which is compressive. Since the surface layers are deformed plastically, their metallurgical characteristics are affected. The finish and geometrical character of the surface may also be changed. Each of these three effects may influence fatigue performance. Independent assessment is extremely difficult and beyond the scope of this paper, although some data pertaining to each are included. Essentially, this paper is concerned with the actual fatigue performance of test specimens, cold worked in various ways and to different degrees, in varied environmental situations.

Surface Working Processes

Shot Peening

The nomenclature, specifications, and control of shot peening have been adequately described in the literature (**1–3**).[1] This process is applicable to parts of almost any shape or size, and may be economically applied to large areas. Figure 1 shows the residual stress distribution in two aluminum alloy cylinders peened with one size of shot to two different intensities. The stress patterns were similar for the two intensities, with a tendency for higher stresses and increased depth of effect for the heavier intensity.



NOTE.—Stress patterns are from combined quenching and peening effects on 1¾-in. diameter cylinder peened with S-230 cast steel shot.

Fig. 1.—Residual stress in shot peened 2014-T6 aluminum.

Almen (**4**) and Fuchs (**5**) have suggested the use of the "dimple diameters" to estimate depth of peening effect. Fuchs presents data showing essentially a 1 to 1 relationship between dimple diameter and depth of compressed layer. These diameters were checked for the peening conditions of the specimens of Fig. 1, and are indicated by dimensions A and B. The residual stresses decrease rapidly beyond the depths equal to these dimple diameters.

Figure 2 from Brodrick (**6**) shows the

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NOTE—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author or authors. Address all communications to ASTM Headquarters, 1916 Race St., Philadelphia 3, Pa.

[1] The boldface numbers in parentheses refer to the list of references appended to this paper.

relation between shot size and depth to which compressive residual stresses are maintained. This shows that maximum depths are obtained by relatively large shot and high intensities. The magnitude of the surface compressive stress did not vary consistently with shot size, but was typically a large fraction of the material's yield strength.

Surface Rolling

Surface rolling is most commonly applied to surfaces of revolution. While outside diameters of cylinders, with or without fillets, are the largest application, inside diameters and flat circular areas have also been rolled. Figure 3 shows a fatigue test specimen being rolled in a lathe.

Figure 4 illustrates the residual stress patterns in two aluminum alloy cylinders rolled with the same roller at different loads and feeds. The smaller load of 25 lb gives a maximum computed ("elastic") contact stress of 250,000 psi. This contact stress is proportional to the cube root of the load; therefore, its magnitude at the 8-times-heavier 200-lb load is twice this, or 500,000 psi. There is considerable difference between the stress patterns resulting from the two conditions. Those resulting from the lighter load are smaller and extend to less depth; the longitudinal and tangential stresses are almost identical for the lighter load, but considerably different for the heavier.

Figure 5 is a micrograph of a sample from the surface of a rolled 2024–T4 specimen. The sample was treated to show the cold working of the surface by revealing the recrystallized structure after reheat treating. The depth of the obviously recrystallized layer is about 0.010 in. The depth of compressive stress in this sample was considerably greater than this.

Attempts have been made to observe a change in surface hardness due to rolling. In aluminum-alloy specimens heat treated to near maximum hardness, then heavily rolled, no effect has been conclusively detected, even with the more superficial hardness techniques such as Rockwell 15-T or 30-T.

Figure 6 shows the effect of roller contour radius and load on specimen surface roughness. The graph at the left shows that roughness is greater for higher loads and smaller contour radii. Generally, however, lighter loads are used for the smaller-radius rollers. The dashed line on this figure joins the loads on each curve where a maximum computed ("elastic") contact stress of 500,000 psi is attained (7). The right-hand graph shows the tendency toward improvement in surface finish as feed is reduced.

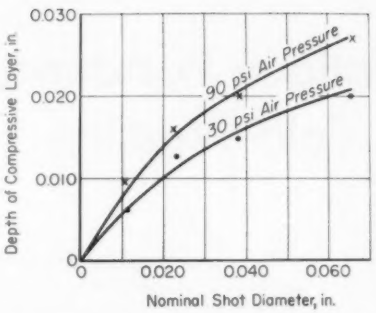


Fig. 2.—Effect of shot size on depth of compressive layer in 7076-T6 aluminum (from reference (6)).

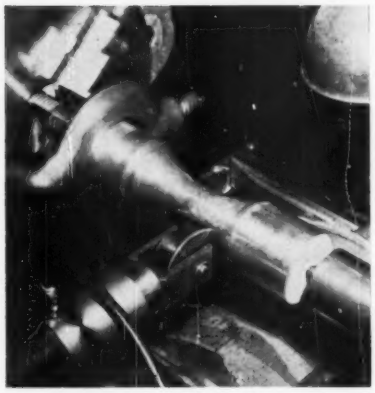
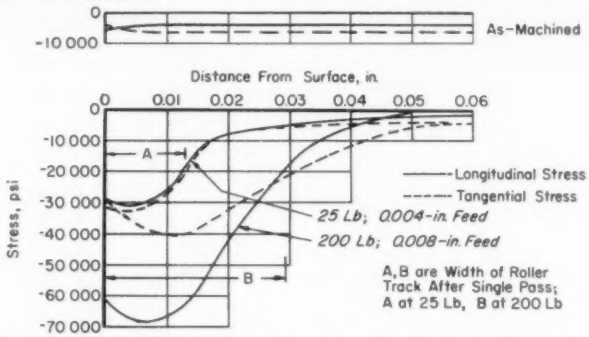


Fig. 3.—Surface rolling of fatigue specimen.



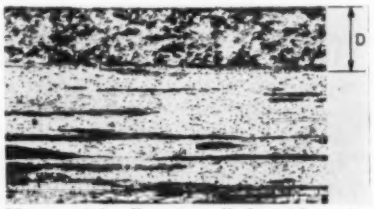
NOTE.—Stress patterns are from combined quenching and rolling effects on 1⅜-in. diameter cylinder rolled with 3-in. diameter by ¼₆-in. radius roller.

Fig. 4.—Residual stress in surface-rolled 2014-T6 aluminum alloy at two rolling intensities.

Cold-Working Specifications and Fatigue Resistance

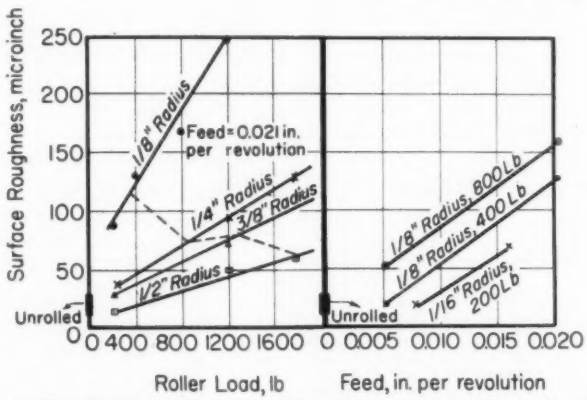
General

The series of tests reported in this section were conducted at Alcoa to show, in a general way, the influence of surface cold working in accordance with certain specifications on fatigue resistance. Most of the work was on 2014-T6 alloy, but several other wrought alloys and one representative casting alloy have been evaluated more



NOTE.—22-in. diameter cylinder with ⅛₆-in. wall; rolled with 3-in. diameter by ¼₆-in. radius roller at 200 lb; Keller's etch. (×100), reduced one half in reproduction.

Fig. 5.—Cold work in surface layers of rolled 2024-T6 aluminum alloy shown by recrystallization depth (D).



NOTE.—1⅜-in. diameter specimen; ¼₆-in. radius roller is 3-in. diameter, others are 1⅜-in diameter. Oil-lubricated during rolling.

Fig. 6.—Effect of roller load and feed on surface finish of 2014-T6.

briefly. Most tests were designed to produce failure in a medium-cycle life range, between 100 thousand and 10 million cycles. In all cases, control data were obtained from "as-machined" specimens in both the notched and unnotched conditions, and the cold worked specimens were tested both with and without subsequent notching. The purpose of this notching was to simulate the many design or service situations where surface cold working might be expected to mitigate harmful effects of surface damage that may occur after the part is placed in use. Notches were cut with a 60-deg V-shape tool producing a root radius of less than 0.001 in. The stresses quoted are based on the section modulus at the root of the notch.

In the interest of making many of these data more understandable and to illustrate trends, such terms as "life factors" and "strength improvements" are used. These terms are somewhat ambiguous, since they are dependent on the relative position of the data on the *S-N* curve. Life factors are used when comparisons were at similar stresses, and strength factors when at similar lives.

Shot Peening

Table I shows the improvements in specimens shot peened and tested without notching. The "fatigue strength improvement" is the percentage by which a stress for a shot-peened specimen exceeds the stress at which a typical control specimen failed at that same life. A considerable range of shot size and intensity is represented in the 2014-T6 specimens, but all results are in a fairly small bracket of 18 to 29 per cent improvement with no obvious correlation of specifications and results. With the 2024-T4 specimens, the improvement was somewhat larger. No further improvement was indicated as a result of "over-peening" with fine shot.

Figure 7 illustrates the effect of peening intensity with a particular shot size on the fatigue life of specimens notched after peening. There are two special points on this figure. One shows that the intense cold working by a $\frac{1}{8}$-in. radius tool in an air hammer gave a very large life increase. A specimen peened after notching showed a much larger improvement than a companion specimen peened before notching. The No. S-230 shot gave effective resistance to the 0.010-in. deep notch, although the intensity needed to be high for improvement. With the 0.020-in. notch, the low peening intensities were ineffectual, but higher ones were helpful. This size shot is not capable, however, of giving the protection afforded by very heavy peening, as shown by the tool-peened specimen. Thus, either shot size or intensity or both must increase as notch depth increases to realize the potential protection offered by shot peening.

Surface Rolling

Table II summarizes the performance of unnotched specimens after various conditions of rolling. The range of conditions covered by these tests can be better appreciated by reference to Fig. 8. These two specimens were the extremes in working, appearance, and surface roughness. One had a surface roughness of 14 microinches; the other surface was too rough to measure by the method used. Yet, the life of the rougher one was 50 per cent greater under the same test conditions.

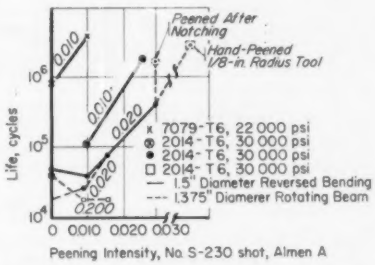
Table III shows the relation between intensity of rolling and life improvement ratio at a given stress level, for specimens notched after rolling. At

TABLE I.—FATIGUE RESISTANCE OF UNNOTCHED SPECIMENS AT VARIOUS SHOT-PEENING CONDITIONS.

Shot Size	Intensity	Fatigue Strength Improvement, per cent
	2014-T6	
S-70	0.006 A	21, 29[a]
S-230	0.009 A	24
S-230	0.016 A	24
S-230	0.028 A	18 to 24[b]
S-550	0.013 A	20
	2024-T4	
S-230	0.010 A	33 to 39[c]
S-230	0.015 A +	32 to 43[b]
S-70	0.006 A Overpeened	32 to 43[b]

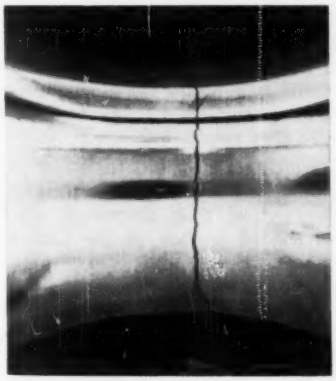
NOTE.—1.5-in. diameter specimens tested in reversed bending. Failures in 0.6 to 6 million cycles.

[a] Two specimens tested.
[b] Three specimens tested.
[c] Four specimens tested.



NOTE.—Figures on curves are notch depths in inches.

Fig. 7.—Effect of shot peening on subsequently notched specimens.



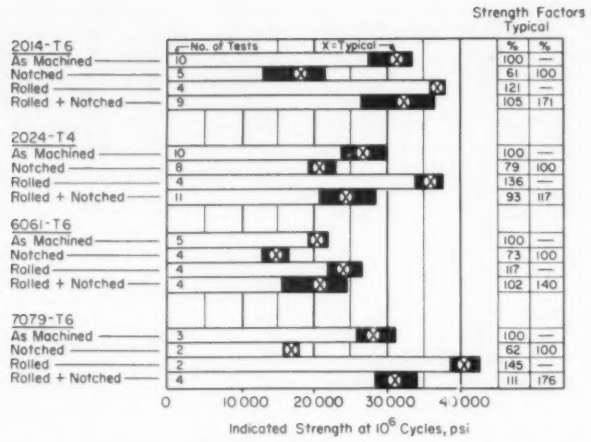
(*top*) Rolled with $\frac{1}{16}$-in. radius by 1.375-in. diameter roller, 200-lb load, 0.021-in. feed. Surface roughness, 14 microinches. Stress, 27,000 psi. Cycles at failure, 7.4 million. (*bottom*) Rolled with $\frac{1}{16}$-in. radius by 1.375-in. diameter roller, 1800 lb load, 0.010-in. feed. Stress, 27,000 psi. Cycles at failure, 10.6 million.

Fig. 8.—2014-T6 fatigue specimens of 1.375-in. diameter rolled under widely different conditions.

TABLE II.—EFFECT OF ROLLING CONDITIONS ON FATIGUE RESISTANCE OF 2014-T6 ALLOY.

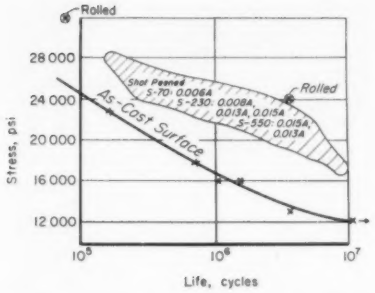
Roller Contour Radius, in.	Roller Feed, in.	Roller Load, lb	Maximum Compressive, Stress, thousands of psi	Indicated "Strength Improvement," per cent
$\frac{1}{16}$	0.008	30–300	260 to 570	11 to 18
$\frac{1}{16}$	0.004	300–600	570 to 720	22 to 36
$\frac{1}{8}$	0.021	200–1800	410 to 860	25 to 32
$\frac{1}{8}$	0.010	200–1800	410 to 860	25 to 30
$\frac{1}{4}$	0.005	400–800	520 to 660	25 to 26
$\frac{1}{4}$	0.021	200–1800	300 to 650	22 to 30
$\frac{3}{8}$	0.021	200–1800	270 to 560	25 to 31
$\frac{1}{2}$	0.021	200–1800	240 to 500	27 to 32
Extreme values (minimum, maximum)				11, 32
Over-all average				27

NOTE.—Specimens rolled with $\frac{1}{16}$-in. radius roller were 1.5-in. diameter, tested in reversed bending. Others were 1.375-in. diameter, tested in rotating bending. Failures in 1- to 20-million cycle range.



NOTE.—1.5-in. diameter specimen in reversed bending. Rolled with 3-in. diameter by $\frac{1}{16}$-in. radius roller at 200 lb load and 0.008-in. feed. Notch 0.020-in. deep.

Fig. 9.—Effect of one rolling condition on the fatigue resistance of four wrought alloys.



NOTE.—1.5-in. diameter specimen tested in reversed bending. C 355-61 T alloy cast by premium process. Rolled with 3-in. diameter by $\frac{1}{16}$-in. radius roller at 200 lb load and 0.008-in feed.

Fig. 10.—Effect of peening and rolling on cast aluminum.

the two highest roller loads, the life of the rolled and 0.020-in. notched specimen was much greater than that of the as-machined specimen without a notch. Specimens with a very deep notch (0.200 in.) showed a definite, but lesser life improvement. Very heavy rolling would be necessary for large improvements in the life of specimens with such a deep notch.

Figure 9 summarizes the effect of a single rolling condition on the fatigue resistance of four aluminum alloys. The shaded portion of the bars encompasses the scatter of the results of the number of specimens tested, shown at the left end of the bar, and the "X" is located at the average strength level typical for the group. The strength factors at the right are based on these typical numbers. The pattern of these factors for an alloy exhibits no obvious correlation with other properties of the alloy. One significant indication is that those alloys which were harmed most by notching when unworked received the most benefit by rolling before notching.

Table IV lists fatigue test results from another wrought alloy, 7075-T6. The data show that rolling at 200 lb load increased the fatigue life of unnotched specimens, but additional load was more beneficial. No further increase is noted in going from 1200 to 1800 lb roller load. The fatigue life of the specimen rolled with a 200-lb load prior to notching was approximately tripled, but at 1800 lb, the life of the rolled specimen was 1250 times that of an untreated specimen.

Figure 10 illustrates the scope of work that has been done on commercial casting alloys. All data are from specimens without notches. The data represent a very large range of shot size and peening intensity. The strength improvement at 1 million cycles ranges from 31 to 56 per cent. A rolled specimen stressed at ±24,000 psi developed a life of 3.5 million cycles; for this life this stress is 81 per cent above that of an as-cast surface specimen.

Test Conditions and Environment

Specimen Design and Loading

Table V lists tests which can be directly compared to show possible effects of specimen size, type of loading, and stress ratio. The first section of this table is concerned with specimens without notches. The rotating-bending or reversed-bending tests show the same order of improvement from rolling. Specimens tested axially at 0 and −1 stress ratio show no significant change when rolled. The specimens tested at a stress ratio of +0.5 show an appreciable loss in strength from rolling

TABLE III.—EFFECT OF VARIOUS ROLLING TREATMENTS ON THE FATIGUE LIFE OF 2014-T6 SPECIMENS NOTCHED AFTER ROLLING AND TESTED AT 30,000 PSI.

Rolling Conditions: Roller Dimensions, in. Diameter	Contour	Load, lb	Feed, in.	Notch Depth, in.	Life, Cycles	Life Factor, $(R+N)/N$
1⅜-IN. DIAMETER ROTATING-BEAM SPECIMENS						
None	...	...	...	None	350 000	...
1⅜	½	1800	0.021	None	4 000 000	...
None	...	...	...	0.020	18 000	...
1⅜	½	200	0.021	0.020	200 000	11
1⅜	½	1200	0.021	0.020	5 000 000	280
1⅜	½	1800	0.021	0.020	6 200 000	340
None	...	...	...	0.200	40 000	...
1⅜	½	1200	0.021	0.200	90 000	2.2
1⅜	½	1800	0.021	0.200	350 000	8.8
1½-IN. DIAMETER REVERSED-BENDING SPECIMENS						
None	...	...	...	None	1 400 000	...
3	1/16	200	0.008	None	10 000 000	...
None	...	...	...	0.020	40 000	...
3	1/16	200	0.008	0.020	2 200 000	55
3	1/16	200	0.016	0.020	1 000 000	25
3	1/16	300	0.004	0.020	9 000 000	225
3	1/16	600	0.004	0.020	6 000 000	150
3	1/16	200	0.016	0.030	540 000	...

NOTE.—$(R+N)$ is life of rolled and notched specimens; (N) is life of untreated specimen with notch.

TABLE IV.—EFFECT OF SURFACE ROLLING ON SMOOTH AND NOTCHED FATIGUE RESISTANCE OF 7075-T6 ALUMINUM ALLOY.

Rolling Condition	Notch Depth, in.	Life at 35,000 psi, cycles	Life Factor	Strength at 10^8 Cycles, psi	Strength, per cent
As machined	None	180 000	1.0	27 500	100
Rolled, 200 lb	None	2 500 000	14	38 000	138
Rolled, 1200 lb	None	15 000 000	83	47 000	171
Rolled, 1800 lb	None	15 000 000	83	47 000	171
As machined	0.020	8 000	1.0	...	...
Rolled, 200 lb	0.020	22 000	2.8	...	...
Rolled, 1800 lb	0.020	10 000 000	1250	45 000	...

NOTE.—1⅜-in. diameter rotating-beam specimens; rolling with 1⅜-in. diameter by ½ in. radius roller at 0.021-in. feed.

TABLE V.—EFFECT OF TYPE OF LOADING, SPECIMEN SIZE, AND STRESS RATIO ON RESPONSE TO ROLLING FOR 2014-T6 ALLOY.

Type Loading	Specimen Diameter, in.	Stress Ratio	Rolling: Contour Radius, in.	Rolling: Load, lb	Maximum Stress at 10^6 Cycles, psi	Per Cent Change Due to Rolling
Specimens Without Notches						
Rotating bending	1.375	−1		None	26 000	
			½	200 to 1800[a]	33 000	+27
Reversed bending	1 500	−1		None	31 000	
			1/16	200	37 500	+21
Rotating bending	0.400	−1		None	34 000	
			½	800	45 000	+32
Axial	1.13	−1		None	25 000	
			1/16	200	25 000	0
Axial	0.300	−1		None	32 000	
			½	480	33 000	+3
Axial	0.300	0		None	51 000	
			½	480	50 000	−2
Axial	0.300	+0.5		None	65 000	
			½	480	56 000	−14
Specimens with 0.020-in.-Deep Sharp V-Notch						
Rotating bending	1.375	−1		None	...	
			½	1200	34 000	
Reversed bending	1.500	−1		None	19 000	
			1/16	200	32 500	+71
Rotating bending	0.400	−1		None	14 000	
			½	800	24 000	+72
Axial	1.13	−1		None	9 500	
			1/16	200	15 000	+58
Axial	0.300	−1		None	7 000	
			½	480	9 000	+29

[a] Range of loads for three specimens. Fatigue results practically identical for all three.

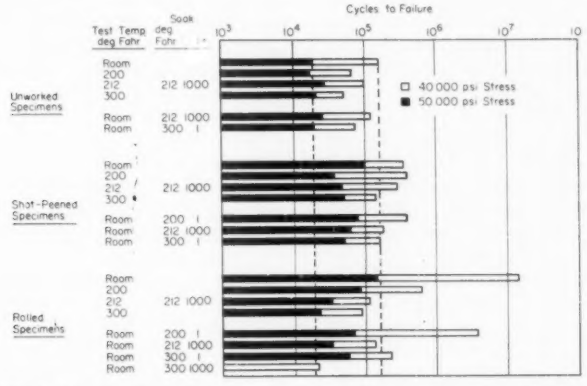


Fig. 11.—Effect of temperature on fatigue life of cold-worked specimens of 2014-T6 alloy.

This loss was verified by several tests of both rolled and unrolled specimens. The maximum stresses at stress ratios of zero and +0.5 are in the plastic range of the material, and one would expect little benefit from cold working, but the loss in strength is surprising and, as yet, unexplained. One possible explanation is the increased surface roughness caused by rolling.

The lower section of Table V shows the various types of notched specimens tested at a stress ratio of −1. The available data do not permit a quantitative comparison to be made of rolling effect alone on the large specimens tested in rotating-bending and reversed-bending. However, the improvements are large, and the absolute values for the rolled and notched specimens in the two situations are quite similar. The large axial specimen showed a somewhat lesser, but still a large, improvement. The level of strength for the notched axial specimens is considerably below those for the bending specimens. This reduction is characteristic of this style of testing (**8**). Improvement for the small axial specimen was about half that for the larger. Note that the notch depth was kept constant in these tests, not its proportion to the specimen diameter.

These data indicate that surface cold working is not useful unless a gradient is present in the applied stresses.

TABLE VI.—EFFECT OF ELEVATED TEMPERATURE ON LIFE OF SURFACE-ROLLED 2014-T6 SPECIMENS TESTED AT 40,000 PSI.

Soak: Temperature, deg, Fahr	Soak: Time, hr	Test Temperature, deg, Fahr	Life Improvement Factor
...		Room	83
...		200	8.7
...		300	1.8
212	1000	Room	1.2
212	1000	212	1.1
200	1	Room	22
300	1	Room	3.6

This gradient may be the type that is produced by bending loads or the local type in the neighborhood of a superficial notch. Neither the large nor the small axially loaded specimens showed any gain from rolling, which produced significant changes in smooth bending and notched axial test specimens. Since there was no improvement in axial specimens at −1 stress ratio, it is not surprising that none was noted at higher stress ratios.

Heating After Cold Working

Much of the effect of surface cold working in improving fatigue resistance is attributed to the residual stresses introduced. Since the elastic limit of materials is reduced at elevated temperatures, one would expect that residual stresses will be relaxed at elevated temperatures by proportions depending

TABLE VII.—EFFECT OF PRESTRESSING BEFORE CORROSION ON SUBSEQUENT FATIGUE LIFE.

Surface Treatment	Strength at 10^8 Cycles, per cent of as-machined strength: 2014-T6	2024-T4	7079-T6	Cast C355-T61
None, corroded	69	83	66	74
Rolled, corroded	122	117	104	...
Shot peened, corroded	81	104	...	108

NOTE.—
1. All specimens of an alloy exposed together, prior to testing, for 1 week by immersion in solution of 5.3 per cent NaCl, 0.3 per cent H_2O_2.
2. Rolled specimens with 3 by 1/16-in. roller at 200 lb, 0.008-in. feed.
3. Shot-peened specimens with S-230 cast steel shot to 0.010 A.
4. Specimens 1.5-in. diameter, tested in reversed bending.

TABLE VIII—EFFECT OF ROLLING 2014-T6 SPECIMENS WITH UNFAVORABLE (TENSILE) RESIDUAL STRESSES.

Preloaded	Rolled	Notched	Strength At 10^6 Cycles, psi	Effect of Preload, per cent	Effect of Rolling, per cent
No	No	No	31 000	...	...
Yes	No	No	17 000	−45	...
Yes	Yes	No	29 500	...	+73
No	No	Yes	19 000	...	...
Yes	No	Yes	12 000	−37	...
Yes	Yes	Yes	26 500	...	+121

NOTE.—1.5-in. diameter specimens tested in reversed bending. Preload produced a bending (Mc/I) stress of 115,000 psi. Rolled with 3-in. diameter by 1/16-in. radius roller at 200 lb, 0.008-in. feed. Notch 0.020-in. deep. All failures on side preloaded in compression.

on the stress level, the temperature, and the time of exposure.

The tests described in Table VI and illustrated in Fig. 11 were conducted on a group of 0.4-in. diameter rotating-bending specimens of 2014–T6 alloy. Some were left untreated, some were shot peened with S-230 shot to 0.016A,[2] and some were rolled with a $1\frac{3}{8}$- by $\frac{1}{2}$-in. roller at 800-lb load and 0.021-in. feed. Tests were run at 40,000 and 50,000 psi at various temperatures, and at room temperature after thermal exposure as indicated.

The lives of the untreated specimens were not greatly affected by the thermal condition imposed. In room-temperature tests, rolling was much more effective than shot peening. In tests at 200 F, the rolled-specimen improvement dropped to approximately 10 per cent of its value at room temperature. When tested at 300 F, the improvement was approximately 2 per cent of its room-temperature value — the effect of rolling had essentially disappeared. Long exposure to 212 F wiped out all significant effects of the rolling. Short exposure to 200 F before testing at room temperature reduced the improvement, but a rolled specimen still had 22 times the life of an unrolled specimen. Short exposure to 300 F further reduced the improvement, but it was still considered significant.

Checking at other temperatures and stress levels and for other alloys is needed before restrictive thermal limits are set. The fact that brief thermal exposure or mechanical overloading can cause plastic action that will reduce the residual stresses set up by earlier cold working is a serious limitation on the use of the methods. The possible future exposure of a machine part to these influences in processing, assembly, installation, or service should be carefully checked before approval of cold-working as a manufacturing process.

Corrosion

Table VII shows how the "notch" effect created by exposure to corrosive environments can be mitigated by cold-working before exposure. The effect of this particular exposure was about the same as that of a 0.020-in.-deep sharp machined notch. In all cases, cold working before exposure gave protection against the reduction in fatigue resistance caused by the corrosion. Rolling led to large improvement; the relatively light shot peening gave less.

Based on visual observation, the apparent attack on unworked and cold worked surfaces were very similar. The observed benefit in fatigue resistance is derived from the residual compressive surface stresses. These surface stresses are also quite effective in increasing resistance to stress corrosion, a mode of failure of certain materials which is only possible in the presence of surface tensile stresses and corrosive environment.

[2] All arc heights are for standard steel Almen test strips.

Unfavorable Residual Stresses

The presence of unfavorable (tensile) residual stresses can reduce the fatigue resistance of metals. Such stresses could be caused by heat treatment, forming or straightening operations, or certain types of machining or grinding. Table VIII summarizes a test designed to simulate this effect and investigate the influence of cold working with such stresses already present. The 2014-T6 specimens were installed in a device in which high static bending loads could be applied. All were loaded in one direction to give a stress (Mc/I) of 115,000 psi. Strain gages placed on one specimen revealed a total strain under load of 2.5 per cent. When the load was removed, the fibers which had received the maximum compressive stress under load were left in a state of tensile residual stress.

The effectiveness of the tensile residual stress in reducing fatigue resistance is shown by the fact that a preloaded smooth specimen showed a 45 per cent loss in strength. A specimen which was preloaded, then notched 0.020 in. deep showed a 37 per cent loss. Each is compared to similar specimens without preload. If the preloaded specimens were subsequently rolled, dramatic improvements were observed. The preloaded, then rolled, specimens, with or without subsequent notching, attained strengths of about 80 per cent of similar specimens without preloading (Fig. 9).

Conclusions

1. Surface cold working can have a large effect on the fatigue resistance of aluminum alloys. The degree of response varies widely, depending on many factors. In certain situations, the fatigue strength of a specimen may be more than doubled.

2. Large specimens without notches, tested in bending at a stress ratio of -1, showed moderate strength improvement from cold working, with little effect of method or intensity of cold working. Similar specimens tested with axial loading derived no significant benefit.

3. The harmful effect of sharp, shallow notches on fatigue resistance can be reduced or cancelled by cold working before notching. Prestressing intensity must be sufficient for the notch depth. Benefits are present in both bending and axial-load tests.

4. All aluminum alloys tested, both wrought and cast, responded significantly to cold working. Relative response varied considerably among the alloys tested.

5. Elevated-temperature exposures which have a small effect on the basic fatigue strength can cause a large reduction in the benefits of cold working.

6. Tensile residual surface stresses can sharply reduce fatigue resistance, while subsequent cold working mitigates this reduction.

7. Aluminum alloy specimens were shot peened as heavily as 0.028A with S-230 shot and 0.013C with S-550 shot. They were rolled to maximum computed ("elastic") contact stresses as high as 860,000 psi. To these limits, there was no indication of reduced fatigue resistance due to excessive intensity.

8. Even though some of the cold working treatments resulted in very rough surfaces, considered unacceptable from an appearance standpoint, fatigue resistance was comparable to other treatments producing smoother surfaces.

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New Methods for Determining Stress-Relaxation*

By G. R. GOHN and A. FOX

Stress-relaxation test methods—either in tension or in compression—are reviewed, and several new methods are described. The vibrating-string technique developed by the authors for tests in tension holds the constrained specimen at constant length, whereas conventional tests allow the constraint to fluctuate between limits. The technique developed by the authors for tests of organic materials in compression permits the use of multiple specimen jigs for obtaining data from replicate tests on the same material or from simultaneous tests on a variety of materials subjected to the same initial strain. Long-time data from both types of test are presented, and evidence is offered to show why it may be difficult to derive reliable long-time stress-relaxation values from constant-load creep data.

THE MAXIMUM utilization of engineering materials required by modern design demands the measurement of mechanical properties[1] which previously were either ignored because they were difficult to determine or were estimated from other more readily measured properties. Stress-relaxation[1]—the time-dependent decrease in stress in a constrained specimen—is one of these properties. It causes the drop in pitch frequently observed in stringed instruments, and more important from an engineering standpoint, it governs all thermal and mechanical processes used for the relief of residual stresses. Relaxation also tends to reduce stress gradients resulting from geometrical factors and nonuniform loads in working parts. Hence stress-relaxation data can be used, not only to develop stress-relief treatments for reducing residual stresses in castings, forgings, welded assemblies, cold worked metals, machined surfaces, and so on, but also to obtain basic information on the permanent tightness of bolted joints, riveted assemblies, shrink fits, gaskets, solderless-wrapped connections, and similar devices.

Until recently, measurement of stress-relaxation was of interest only to those concerned with the design and manufacture of steam- and power-generating equipment such as boilers and turbines and, to a lesser extent, those concerned with the design of gaskets, electric motors, and dynamos. Thus we find that a considerable amount of work in this field has been done by the ASTM-ASME Joint Committee on the Effect of Temperature on the Properties of Metals (**1**)[2] and by individuals associated with the activities of that committee. Today, reactor, missile, and satellite design has created a broader interest in the subject. For example, at the 1960 Annual Meeting of ASTM, Kennedy and Douglas (**2**) of the Atomic Energy Commission described stress-relaxation equipment which they had developed to obtain a more precise measure of the instantaneous strain[1] in metals tested at temperatures ranging from 1500 to 1650 F. At the same meeting, Freudenthal (**3**) discussed the physical origin, mathematical representation, experimental determination, and the design significance of stress-relaxation, with particular emphasis on the interrelation of creep[1] and relaxation. Morgan (**4**) has emphasized the value of a true relaxation test in furnishing a clue to the general time-dependent behavior of the materials used in today's designs; while a recent report issued by the Office of the Director of Defense Research and Engineering (**5**) cites the need for "a continued effort to develop and secure national standardization of test methods for organic materials, particularly . . . for creep and stress-relaxation data, including standard methods of presentation."

It therefore seems desirable to review the test methods that have been used previously to evaluate stress-relax tion, to describe some modifications of those test methods which were developed to facilitate the procurement of engineering data on a large number of specimens over extended periods of time, and to show why attempts to derive stress-relaxation data from creep tests are not a fundamental approach to the problem but are primarily methods for empirical curve fitting.

Theory and Review of Prior Work

More than one hundred articles on stress-relaxation have appeared in the technical literature during the past 15 years. A few of these, such as *ASTM STP No. 187* (**1**), contain data most of which have been obtained from modified creep tests rather than from pure relaxation studies. The number of references dealing with test methods are even fewer. Most of the authors were trying to develop a functional relationship between creep and stress-relaxation—in the early days to estimate long-time creep from "step-down" creep tests and in recent years to estimate stress-relaxation from the more readily available creep data.

Most of the work reported in the literature deals with stress-relaxation in materials initially stressed below their yield strength.[1] While this limitation on

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[1] These terms are more precisely defined in Tentative Definitions of Terms Relating to Mechanical Testing (E 6-60 T), 1960 Supplement to Book of ASTM Standards, Parts 3, 4, 5, 6, 9, and 10.

[2] The boldface numbers in parentheses refer to the list of references appended to this paper.

GEORGE R. GOHN, a member of the Research Department of the Bell Telephone Laboratories Inc., in New York City has been concerned with creep and stress relaxation tests and the development of special equipment for making such tests for more than 15 years. He received his A.B. from Otterbein College in 1926, a B.S. in Engineering and a Met. Eng. degree from the School of Mines, Columbia University in 1929.

ALFRED FOX has been concerned with stress relaxation and creep studies at the Bell Telephone Laboratories Inc., in New York City since 1955. At present he is a senior in the Mechanical Engineering Department of Cooper Union.

the initial stress is not a prerequisite, it does facilitate the development of a simpler model to explain the phenomenon. Thus, when the specimen is first stressed, an instantaneous strain is developed which is proportional to the applied load. This may be expressed as

$$\epsilon_i = \frac{P_o/A_o}{E} \quad \text{or} \quad \frac{\sigma_i}{E} \ldots\ldots (1)$$

where:

ϵ_i = instantaneous strain,
P_o = applied load,
A_o = original cross-sectional area of the test specimen,
σ_i = initial stress, and
E = modulus of elasticity[1] of the material under test.

Since the specimen is constrained and the initial strain is presumed to be elastic, there can be no change in the residual stress unless some of this elastic strain is converted into time-dependent plastic strain. This hypothesis presumes viscous flow at constant total strain. While according to the basic definition of stress-relaxation the constraint need not be constant in order for this phenomenon to occur, this restriction is desirable if a quantitative measure is to be obtained. If the constraint is held constant, then

$$\epsilon_i = \epsilon \ldots\ldots (2)$$

where ϵ = total strain at time t. If stress-relaxation occurs, then at any time t greater than zero the total strain is composed of two components, one elastic or recoverable, the other plastic or irrecoverable. Therefore:

$$\epsilon_i = \epsilon = \epsilon_e + \epsilon_p \ldots\ldots (3)$$

where:

ϵ_e = the residual elastic strain at any time t, and
ϵ_p = plastic strain at time t.

The latter, ϵ_p, is equal to the residual strain after removal of the constraint and can be measured. From this value the loss in stress, $\Delta\sigma$, which cannot be measured, can be calculated as equivalent to the stress required to produce an equal amount of elastic deformation. Thus, on the assumption that the modulus of elasticity is constant and that the change in cross-sectional area is negligible during the test,

$$\Delta\sigma = \sigma_i - \sigma_t = E\epsilon_p \ldots\ldots (4)$$

where σ_t = stress at time t. Or again, since stress can never be measured but only calculated from the established theories of elasticity and viscous flow, the constraint can first be removed to permit instantaneous recovery[1] after which the specimen can be reloaded until the constrained length is again $L_o(1+\epsilon_i)$, where L_o = original gage length of the test specimen at zero load. Since there is now some residual plastic strain, ϵ_p, the elastic strain, ϵ_e, required to restore the constrained length to the value $L_o(1+\epsilon_i)$ is less than ϵ_i. From this it follows that the applied load required to deform the specimen by the reduced amount will be less than the initial load. In this case, the residual stress may be calculated either from the relation

$$\sigma_t = P_t/A_o \ldots\ldots (5)$$

where P_t = new load required to deform the specimen to the original constrained length $L_o(1+\epsilon_i)$, or from the relation

$$\sigma_t = E\epsilon_e \ldots\ldots (6)$$

Repetition of either of these load-unload-reload procedures would give data such as those reported by Davis (**6**) from which the stress-relaxation curve can be developed. However, unless a new specimen is used for each successive loading test the prior stress history will affect the rate at which elastic strain is converted into plastic strain. Hence the stress-relaxation curve obtained from the repeated loading and unloading of a single specimen will differ somewhat from the true relation.

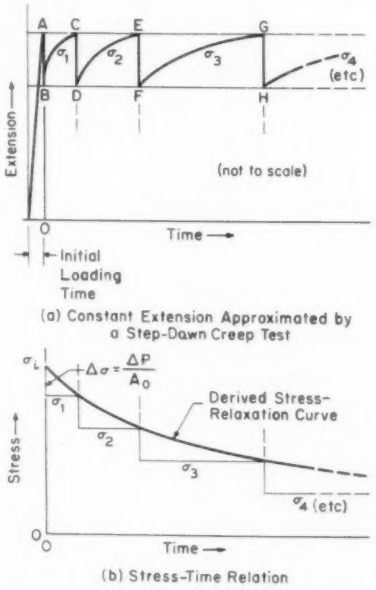

Fig. 1.—Derivation of stress-relaxation curve from step-down creep test.

While either one of the foregoing procedures can be used to measure stress-relaxation, neither one readily lends itself to the design of a machine for automatically recording the required values. Possibly for this reason all of the stress-relaxation data, with but few exceptions, have been derived from "step-down" or interrupted creep tests.

In the step-down creep test, which is termed a "flow rate test" in reference (**1**), a specimen is subjected to a load which causes an initial extension such as OA in Fig. 1(*a*). The load is applied as quickly as possible without impact and the maximum deformation measured, after which an increment of load ΔP is removed. Upon removal of the load there is elastic recovery corresponding to AB, but, under the remaining load, $P_o - \Delta P$, creep is initiated and follows the path BC. When the total length is again equal to the original value of $L_o(1+\epsilon_i)$ a second increment of load ΔP is removed. Under this reduced load a somewhat longer time is required to deform the specimen to the original value, $L_o(1+\epsilon_i)$, that is, creep may now be assumed to follow the curve DE of Fig. 1(*a*) rather than the curve BC. By repetition of this procedure data are obtained which, when plotted in the form of a residual stress-elapsed time curve (see Fig. 1(*b*)), will approximate the stress-relaxation curve.

If in the step-down creep test the load is reduced each time the limiting strain ϵ_i is attained, the average strain will be less than the limiting value. In other tests in which the load is not reduced until after a limiting amount of creep occurs, the average strain will exceed the limiting value. Obviously while the mechanism of these two tests is the same, the creep rates in the two will differ because the two loads (or their equivalent stresses) are slightly different. This may produce some differences in the approximations to the derived stress-relaxation curve.

The step-down procedure can be mechanized, and, if the load increments are sufficiently small, the agreement between the curves derived from data obtained in this type of test and from a stress-relaxation test should be very close. The mechanisms are essentially the same in both. The initial deformation causes a mechanically and thermodynamically unstable condition in the metallurgical structure which, in time, tends to revert to a condition of thermodynamic equilibrium. The various mechanisms by which this equilibrium is attained are discussed by Freudenthal (**3**).

On the other hand, derivations of stress-relaxation values from constant-load creep tests involve two phenomena in which the mechanisms differ. In the stress-relaxation test the specimen is initially stressed and then, through time-dependent rearrangement of the internal structure, is permitted to approach a condition of thermodynamic equilibrium. This is possible because, aside from the load causing the initial instability, no further external disturbing force is introduced. The change in residual stress must therefore be due solely to a reduction in

the internal forces, which decreases the applied force necessary to maintain the constraint. In contrast, the constant-load creep test involves a series of tests at different load (stress) levels which, except for one condition, that is, when the secondary creep rate is zero, maintain the structure of the specimen in a continuous state of mechanical and thermodynamic instability under the action of the external forces. It is obvious that the mechanism of plastic deformation following the initial straining must be different in stress-relaxation tests than it is in constant-load creep tests. Therefore any attempt to use constant-load creep data for the solution of the variable stress condition (stress-relaxation) may give unreliable results. The importance of the differences discussed in the preceding paragraphs is also pointed out by Chernashkin and Livchak (**7**). These differences are further emphasized by Kennedy and Douglas (**2**), who state that the relaxation test is not a substitute for the creep test. They also led Freudenthal (**3**) to conclude that conventional equations for correlating creep and stress-relaxation are unreliable and that the use of such equations must lead to erroneous values for residual stresses when the latter are obtained by conversion and extrapolation of creep data.

As early as 1932, Robinson (**8**) derived stress-relaxation data from constant-load creep tests. In 1937 Boyd (**9**) developed stress-relaxation equipment based upon the interrupted creep technique. In Boyd's equipment load was applied to the specimen through loading springs which could be extended or released by means of a motor-driven screw drive actuated by a pair of contacts. These were operated by the relative displacement of a dial gage plunger and four comparison specimens to which the dial gage was mounted by means of a frame. This device caused the dial gage to respond and the motor to operate on a change in length of about 1/75,000 in. over a gage length of 20 in. The length of the specimen was thus held constant at 20 $\pm$1/75,000 in. This corresponds to a change in stress of approximately 10 psi in the copper wire which he tested. Practically all of the investigators who followed Boyd have used the same basic procedure. Some improvements have been added, notably by Nadai and Boyd (**10**) in 1938, and Kennedy and Douglas (**2**) in 1960. Nadai and Boyd substituted a screw drive and isoelastic springs for the helical springs and screw drive used by Boyd to vary the load required to maintain constant strain in the test specimen. This permitted a more rapid determination of the initial strain. Kennedy and Douglas replaced the screw and spring setup with a pneumatic motor drive which enabled them to determine more precisely the instantaneous strain in materials tested at elevated temperatures (1500 to 1650 F). But despite these improvements, the test procedures are essentially as described by Boyd in 1937. All use the step-down technique which allows limited creep to occur before the specimen is restored to its original constrained length.

In contrast to the step-down creep technique a method has been developed (apparently independently in three countries) for evaluating pure stress-relaxation in tension. This technique is based upon the principle that the frequency of vibration of a vibrating string[3] fixed at both ends is a function of the tension in the string.

$$f = \frac{n}{2L}\sqrt{\frac{T}{\mu}} \quad \ldots\ldots\ldots (7)$$

where:

f = frequency, cps,
n = number of the harmonic, (the fundamental = 1),
L = nodal length of string, in.,
T = tensile force in string, lb, and
μ = line mass density, slugs per in.

By substitution and conversion Eq 7 reduces to

$$\sigma = \left[\frac{(1.0364 \times 10^{-2})L^2\rho}{n^2}\right] f^2 \ldots (8)$$

where:

σ = stress in the string, psi,
ρ = weight density, lb per cu in., and
n = 1, if the fundamental frequency is used.

As early as 1944, Mooney, Wolstenholme, and Villars (**11**) used this technique to determine stress-relaxation in rubber. In their tests the specimen was mounted in a mechanical oscillator with a continuously variable frequency, and the frequency of resonance was observed.

In 1948, Dawance (**12**), in an article published in French by the Technical Institute of Public Works in Paris but not available in this country until quite recently, used the vibrating string technique to measure stress-relaxation in steel wires intended for use in prestressed concrete. Specimens approximately 1 m long with diameters of 2 to 5 mm were stretched on a rigid frame formed by a U-shaped steel beam. The stretched wires were anchored at both ends in hardened steel clamps. A screw and nut combination permitted adjustment of the initial tension to the desired value. Electromagnets were used to vibrate the wire periodically and the resulting frequency measured in a Coyne apparatus calibrated against a tuning fork. Further details of the equipment are not available. However, since the fundamental frequency of the vibrating test specimens was generally too low for accurate measurement on his apparatus, Dawance made most of his measurements at harmonic frequencies.

In 1953, Gohn and Bedell (**13**), in a Technical Memorandum circulated only within the Bell System, described a multispecimen device employing the vibrating string technique which they developed for measuring stress-relaxation in copper wires intended for use in solderless wrapped connections. This equipment, which differs markedly from that used by Mooney, et al, or by Daw-

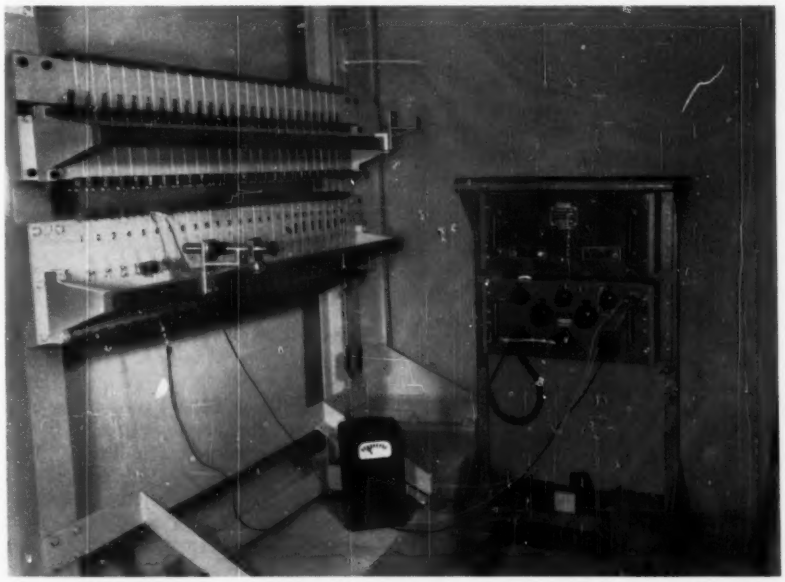

Fig. 2.—Multispecimen equipment for measuring stress-relaxation in tension (frequency method).

[3] A string is defined as a specimen in which the cross-sectional area is small compared to its length.

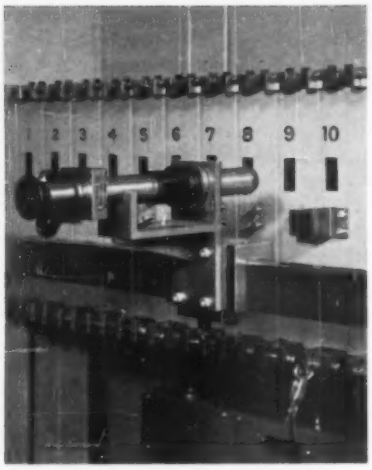

Fig. 3.—Close-up of test specimen and permanent magnet.

ance, is described in greater detail in the section on Test Methods.

In 1960, Chernashkin and Livchak (**7**) described in a Russian periodical equipment similar to that used by Dawance which they had developed for stress-relaxation studies on high-strength wires at normal temperatures. Again, the details of the test equipment are incomplete, but it would appear that a current alternating at the frequency of the vibrating string was fed into one of the axes of an oscilloscope, a current having a known frequency from a frequency generator into the other, and the frequency of the former determined by means of the Lissajous figure.

For stress-relaxation tests in compression, Wright (**14**) employed a variation of the "cold-flow" creep test. In this test, specimens are constrained between anvils attached to the upper and lower platens of a precision dieset. The specimen—usually two or more thicknesses of a plastic sheet material—is mounted in a column in series with a hollow aluminum tube to which are attached SR-4 strain gages. The latter combination forms a load cell and permits measurement of any change in strain in the aluminum tube due to elastic followup which accompanies any cold flow in the plastic. The change in stress in the plastic may be obtained from a calibration curve of the aluminum load cell which must be checked periodically for any zero drift.

Test Methods

For pure stress-relaxation tests in tension the authors used the vibrating-string technique, employing the multi-specimen equipment shown in Figs. 2 and 3. Basically this apparatus consists of two rigid panels—in this case, two 1- by 10-in. aluminum-alloy plates, mounted on vertical aluminum-alloy H-beams. Two clamps, one mounted on the upper edge, the other on the lower edge of these plates, provide means for fastening the wire test specimen to cylindrical stainless steel arbors through which the wire can be threaded and around which it can be wrapped for tensioning as in a piano or any other stringed instrument. One of these clamps is grounded to the frame, the other insulated by a piece of anodized aluminum. At present two panels holding 25 specimens each are used, but provision has been made for the addition of one more panel.

In use, a portable U-shaped permanent magnet made from Alnico-5 is mounted on the aluminum-alloy plate in such a way that the test specimen being measured is parallel to the planes of the pole faces (soft iron) and centrally located in the air gap of the magnet. An alternating electromotive force from a precision oscillator is then applied to the test specimen through a common ground (the grounded test panel) and the end of the specimen attached to the insulated clamp. The rms voltage of this alternating electromotive force should be held constant for precise results. This can be controlled by introducing an electronic (Ballantine) voltmeter into the circuit as shown in the block diagram of Fig. 4. The precision oscillator has a range of 0.01 to 11,000 cps and a readability of 0.01 cps, is stable after preliminary heating, and has an accuracy of 0.01 per cent or better. For calibration of the oscillator, the output is checked against a standard frequency by means of an oscilloscope. It may also be checked against a frequency counter but the latter is less precise.

In the circuit used, the alternating current varies with the magnetic field in accordance with the fundamental physical relation:

$$F = \frac{IL \times B}{C} \quad \ldots\ldots\ldots (9)$$

where:

F = force, dynes,
I = current, amp,
L = length of specimen, cm,
B = magnetic field intensity, gausses, and
C = conversion constant.

Driven by this force, the specimen vibrates in the plane of the air gap. When the frequency of the driving force corresponds to the resonant frequency of the stressed wire the latter vibrates at maximum amplitude. This is determined optically by means of a microscope equipped with a filar eyepiece. The precision oscillator is used not only to drive the test specimen but also to measure the resonant frequency from which the value of the residual stress can be calculated in accordance

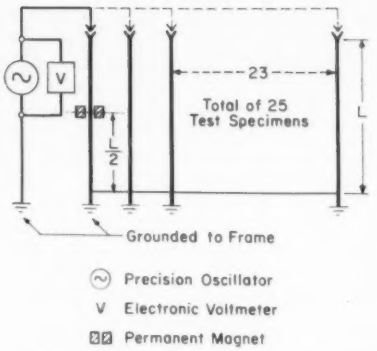

Fig. 4.—Schematic diagram of test circuit.

with Eq 8. In the case of our tests on tinned copper wire having a diameter of 0.0201 in., a length of 10 in., and a density of 0.323 lb per cu in.,[4] this equation reduces to:

$$\sigma = 0.3348f^2 \quad \ldots\ldots\ldots (10)$$

Periodic vibration of the wires and measurement of the resonant frequencies yield data from which the stress-relaxation curve can be developed.

The amplitude of the vibrating specimen is kept to a minimum during measurement of the resonant frequency. This is done by keeping the driving voltage at approximately 2 v (rms). Under these conditions the maximum amplitude of the vibrating specimen does not exceed 0.010 in. The added fluctuating strain corresponding to this deflection is 0.0000025, which, in the case of the copper wire would correspond to a stress of 35 psi. This is negligible for the range of stresses investigated. The added alternating stress is applied to the specimen for less than 30 sec at intervals of not less than 1 hr at the start of the test and at intervals of 500 hr or longer as the test progresses, so that both the creep and fatigue induced by it may be neglected. With the equipment used, in which different materials are mounted on an aluminum-alloy frame, temperature variations will also affect the test results owing to differences in the coefficients of thermal expansion. For example, in the case of copper, a temperature change of 1 F will cause a change in stress of 40 psi; for Kovar, the change would be approximately 150 psi. Since the maximum variation in temperature during a test was only ±2.5 F, and seldom more than ±1 F, changes in stress due to temperature variations have been neglected.

The equipment described can be used not only at normal temperatures but also at elevated temperatures within the limitations of the permanent magnet, provided the entire frame is at temperature. Smaller units holding up to five specimens have been used for ele-

[4] The average density reported from two check tests using three replicate samples for each test.

vated-temperature studies. In this case, the entire frame, as well as the test specimens, are at temperature. However, the substitution of an electromagnet for the permanent magnet would permit operation at even higher temperatures. If the test temperature is not constant, it is desirable to have the test frame made from material having the same coefficient of expansion as the specimens under test and a uniform rate of heating. If this cannot be done, the test frame and the specimen should be at temperature before the specimens are stressed.

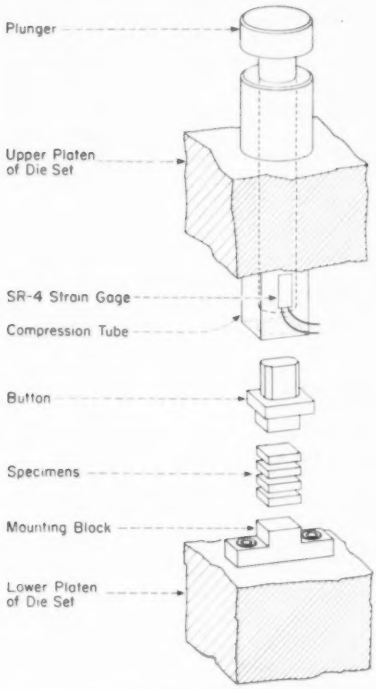

Fig. 5.—Single-specimen jig using a universal testing machine for stress-relaxation measurements in compression.

The stress-frequency relation calculated from Eq 8 may be checked by means of dead loads and a special knife-edge clamp. The stress obtained from Eq 8 and that calculated by dividing the dead load applied to the test specimen by the cross-sectional area of the latter must agree if the constants used in Eq 8 are correct. To check this, the frequency corresponding to a desired initial stress may be calculated from Eq 8, the oscillator set to that frequency, and the specimen clamped after applying the dead load. The specimen should resonate at the instant of clamping.

In the case of the materials tested by the authors the frequency ranged from 350 to 50 cps. This frequency range corresponds to a stress range of 40,000 to 800 psi for materials having a density of 0.278 to 0.323 lb per cu in.

[5] This jig has since been redesigned so that five test positions are now available in each die-set. They may be used for replicate tests or, by the insertion of shims, for tests at five different stress levels.

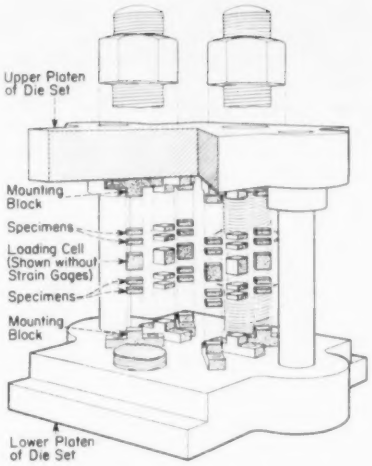

Fig. 6.—Multispecimen jig using load cells for stress-relaxation measurements in compression.

For compression tests, the authors first developed the device shown in Fig. 5.[5] This is essentially a modification of Wright's (14) original "cold-flow" creep setup except that one material, stainless steel, was used for all but the precision die-set. This was done to minimize thermal effects for which Wright found it necessary to apply a correction factor. In the redesigned equipment the compression tube is used only to transmit load to the test specimen and not for measurement as in the earlier design. For measurement of the loads from which the residual stresses in the specimen can be calculated, the jig is set up in a universal testing machine, the load applied to the central plunger, and the value required to just transfer all compression forces from the tube to the plunger measured on the load

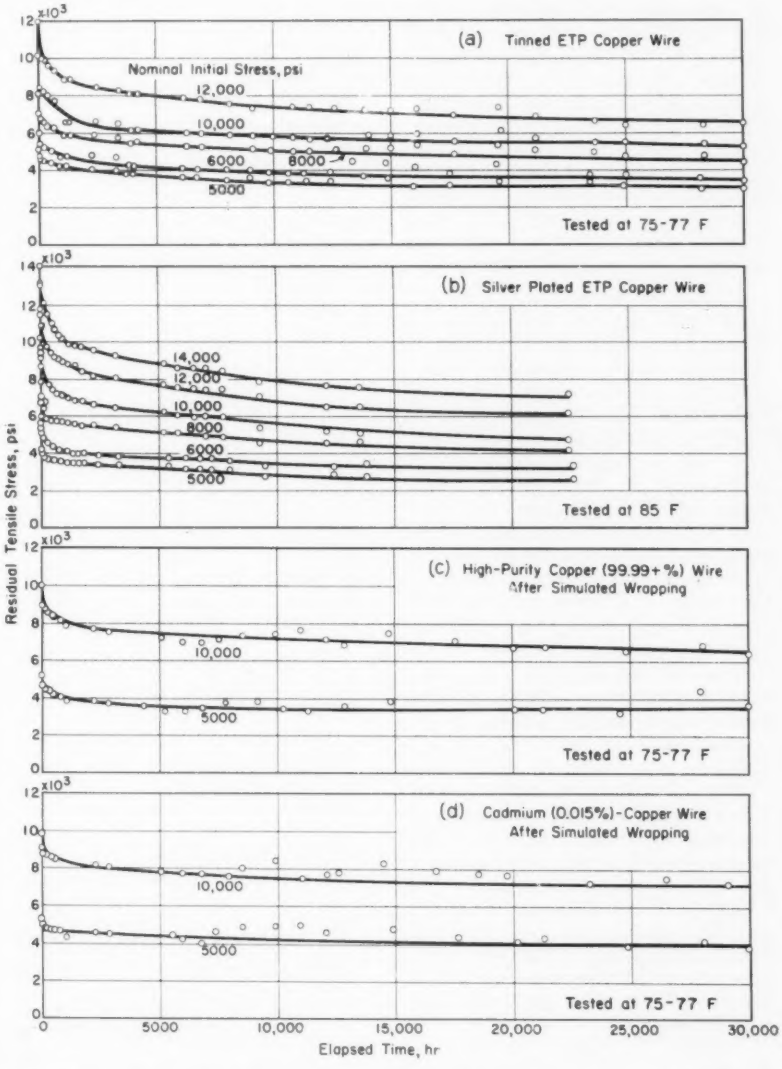

Fig. 7.—Stress-relaxation (tension) curves for annealed copper wires, nominal diameter 0.0201 in. (frequency method).

dial of the testing machine. To determine this point accurately, strain gages are applied to the hollow tube. With this arrangement a constant strain output is indicated until transfer of the load begins. At this point, the strain output of the gages increases owing to a decrease in the compressive load. This increase continues as the load is transferred, and finally the strain levels off when the entire load is carried by the plunger. The use of electrical resistance strain gages in this manner introduces no error even if there should be drift in the zero readings of the gages.

The authors were faced with the need for designing better equipment for determining stress-relaxation in compression—equipment small enough to be placed in contant-temperature rooms already filled with other equipment and sufficiently portable so that it could be transferred from a high-temperature room to cold boxes and back again for cycling studies. A further requirement was that it had to be large enough so that replicate tests could be run simultaneously on the same material or multiple tests on a variety of materials subjected to the same initial constraint. Die-sets are ideal for this work since they permit loading through the adjusting screws, provide lock nuts for holding the constraint constant, and afford sufficient space for six or more test specimens in one setup.

A multiple-specimen device meeting these requirements for stress-relaxation tests in compression is shown in Fig. 6. While the device is similar to that previously described, load cells have been used instead of a testing machine to detect any change in residual stress. Their use is possible because of the development of better strain gages, particularly foil gages and epoxy-resin cements for mounting the gages. This combination has practically no zero drift under the conditions of service, provided the cement is properly cured and the gage leads are coated with a moisture-proof lacquer. The load cells consist of $\frac{1}{2}$-in. stainless steel cubes with four foil-type strain gages mounted in series to form a full four-gage bridge. In this arrangement, two gages are mounted with their axes parallel to the direction of the applied load, two at right angles. This not only provides a temperature-compensating arrangement but increases the gage output per unit strain. In the case of the cells used, the maximum load is approximately 3000 lb; hence the maximum deformation of the cell (which corresponds to the maximum deformation of the test specimens) is only 0.0004 in. for a change in stress of 12,000 psi.

Test Data

Stress-relaxation data obtained in tension tests using the vibrating-string technique are presented in Fig. 7 for tinned annealed ETP copper, silver-plated annealed ETP copper, annealed high-purity (99.99+ per cent) copper, and annealed cadmium (0.015 per cent) copper wires. The last two were tested after simulated wrapping tests in which the wires, under a load of 1300 g, were drawn over a steel mandrel having a radius of 0.017 in., the angle of contact between the wire and the mandrel being 90 deg. As the wire was pulled over the mandrel it was rotated about its own axis at a speed which imparted a twist of two turns per inch. This treatment simulates the process applied by a Keller tool to hook-up wire in solderless wrapped connections and leaves the wire in a stressed condition comparable to that found in service where this type of connection is used.

Figure 8 presents stress-relaxation data in tension for 40 per cent conductivity tinned annealed Copperweld wire in two diameters, for processed Dumet wire, a material having a core of 43 per cent nickel, 50 per cent iron coated with 30 per cent by weight of copper, and for processed Kovar wire, a material having a thermal coefficient of expansion comparable to that of Corning Glass Works No. 7052 glass. Kovar has a nominal composition of 29 per cent nickel, 17 per cent cobalt, and the balance of iron. The Dumet wire was made by swaging and drawing the duplex material. After drawing to size, both the Dumet and the Kovar wires were given a series of anneals and heat treatments which simulate the use of this material in a glass-sealed product. In this process, three anneals are used, 1100 C for 30 min, 750 C for 10 min, and 975 C for a shorter period of time. The stresses in the tests on the three composite materials were computed

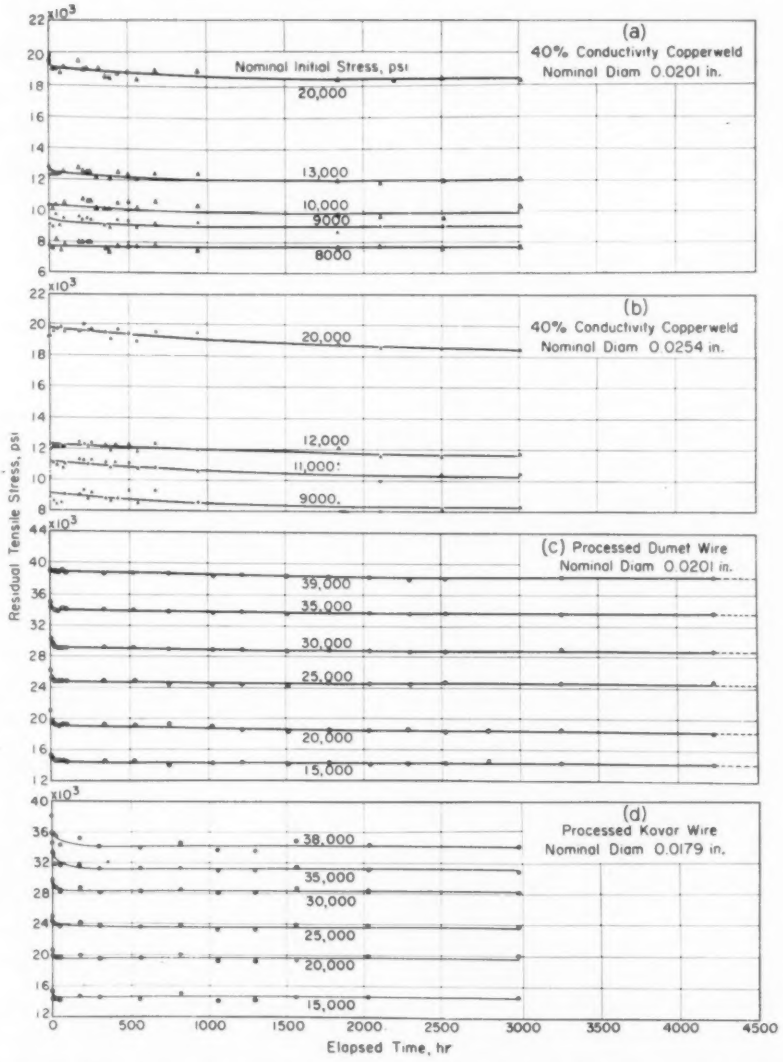

Fig. 8.—Stress-relaxation (tension) curves for Copperweld and nickel alloy wires; tested at 85 F (frequency method).

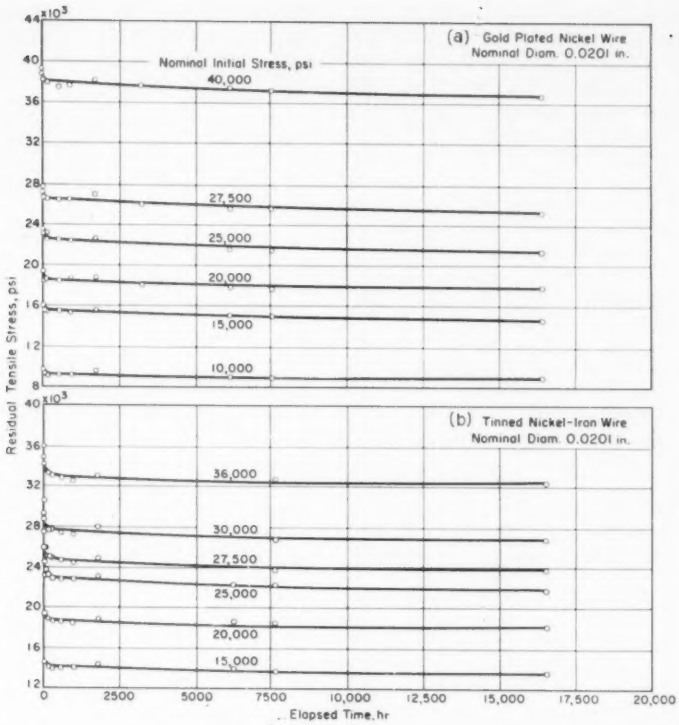

Fig. 9.—Stress-relaxation (tension) curves for nickel and nickel alloy wires; tested at 85 F (frequency method).

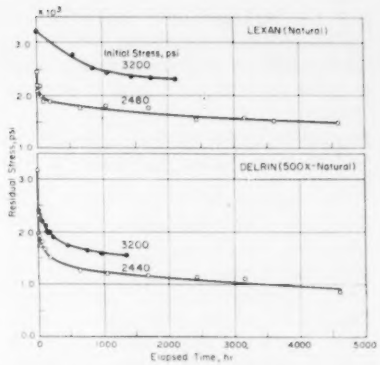

Fig. 10.—Stress-relaxation (compression) curves for thermoplastic compounds tested at 71 to 73 F and 50 per cent RH.

from Eq 8 using a measured value for the density.

Figure 9 shows stress-relaxation data in tension for nickel wire plated with 0.0001 in. of gold and for 50-50 nickel-iron wire having a fused tin finish.

Figure 10 presents stress-relaxation data in compression for specimens of Delrin (du Pont 500—Natural)[6] and Lexan (General Electric 100-01-Natural).[7] The former is an acetal resin thermoplastic, the latter a polycarbonate thermoplastic. Both were tested in the form of $\frac{1}{2}$-in. squares machined from $\frac{1}{8}$-in. thick sheets and tested in a stack of four. These tests were made on the plunger-type jig in which loads corresponding to the residual stresses are read on a universal testing machine. Somewhat different results might be obtained with the use of specimens of different thickness since the cold flow (creep in compression) is known to be a function of the ratio of height to area. However, a thickness of $\frac{1}{8}$ in. was chosen as being representative of the material in service. In making such tests, the same precautions must be used as those specified in Section 3 of ASTM Methods E 9,[8] otherwise reproducible results may not be obtained.

Discussion of Data

The stress-relaxation data obtained in vibrating-string tests on tinned annealed ETP copper wire were compared with the results of stress—relaxation data from two variations of the step-down creep test. In one of these, the loads were manually reduced periodically over a period of years; in the other, an Instron testing machine was used to maintain constant strain on the specimen while the residual load was read from the chart of an automatic load-strain recorder. As shown in Fig. 12, all three methods yielded curves which, from an engineering standpoint, are in good agreement.

The work of Dawance (12) indicates that the frequency method can be applied to wire or rod samples as large as 0.2 in. in diameter. When testing magnetic materials, the air gap must be increased. For large diameter specimens, more power is required to drive them, and tests require the use of a stronger magnetic field than that normally obtained with a permanent magnet.

Stress-relaxation curves on the ETP copper wire show no indication of becoming asymptotic with the time axis, even after 30,000 hr. In the case of the Copperweld, Dumet, nickel, nickel-iron, and Kovar wires the relaxation rate decreases rapidly after 1000 to 3000 hr,

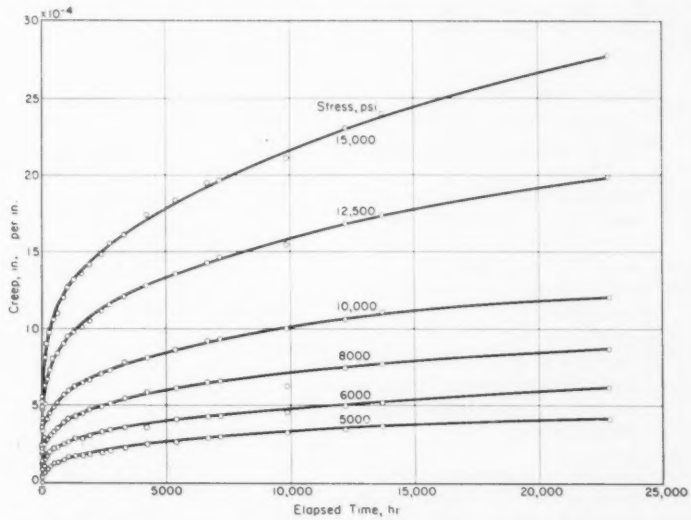

Fig. 11.—Constant-load creep curves for silver-plated, annealed ETP copper wire; tested at 85 F; 50-in. extensometer; nominal diameter 0.0201 in.

[6] Originally designated Delrin (500 X—Natural).
[7] Originally designated Lexan (Natural).
[8] Methods of Compression Testing of Metallic Materials (E 9-59 T), 1959 Supplement to Book of ASTM Standards, Part 3, p. 1.

but the measurements made on the nickel and the nickel-iron alloy wire after 16,500 hr show that stress-relaxation has not entirely ceased.

Derivation of Stress-Relaxation from Step-down Creep Tests

The inadequacy of theories by which the shape of the relaxation curve can be predicted from data observed in creep tests was discussed by Davis (**15**) in 1943. In the intervening years many theories have been proposed for correlating creep and relaxation. Nevertheless, 18 years later Davis' conclusion that no satisfactory theory exists which can be used to predict stress relaxation from tensile creep data still appears to be valid (**3**).

Probably the most widely accepted relation for obtaining stress-relaxation values from creep data is Eq 1 of *ASTM STP No. 187* (**1**). This relationship is, however, not recommended by the Joint Committee for computing stress-relaxation values from constant-load (or constant-stress) creep data. Instead this relationship should be used only for deriving stress-relaxation curves from step-down or "flow-rate" creep curves. For those who would like to develop some other correlation between constant-load creep and stress-relaxation, creep data are given in Fig. 11 for the same silver-plated annealed ETP copper wire as that used in the stress-relaxation tests reported in Fig. 7(*b*). The creep data cover a series of stresses ranging from 5000 to 15,000 psi and an elapsed time of 22,500 hr.

Equation 1 of *ASTM STP No. 187* (**1**) states that

$$(n-1)tr_0E\sigma^{(n-1)} = b\sigma_0^n \quad \ldots (11)$$

where n = per cent change in creep rate per per cent change in stress, that is, the reciprocal of the slope of the line of the log-log plot of residual stress versus creep rate or:

$$n = \frac{\text{change in log creep rate}}{\text{change in log stress}},$$

σ = residual stress after an elapsed time t,

σ_0 = the creep strength for a nominal creep rate r_0, that is, the stress corresponding to a given secondary creep rate,

E = modulus of elasticity at the test temperature,

t = elapsed time, and

b = the elasticity factor; that is, the ratio of total system elasticity to that of the specimen subjected to creep.

According to *STP 187* (**1**) this relationship is strictly valid only for materials and test conditions which yield a linear log-log plot of residual stress versus time having a slope $(n-1)$ and for sufficiently long times that the residual stress is small compared to the initial stress level. Despite these restrictions, the relation expressed by Eq 11 is the only one recommended by the ASTM-ASME Joint Committee on Effect of Temperature on the Properties of Metals (**1**).

Our studies indicate that there is a typographical error in the explanation of the various symbols used in *STP 187* (**1**) for Eq 11 since the results obtained by Robinson (**16**) from the use of this equation can only be obtained if the slope of the log-log plot of residual stresses versus time is equal to $-[1/(n-1)]$ rather than $(n-1)$.

The calculation of relaxation curves from step-down creep data on the basis of the relation described by Eq 11 requires some modifications in the basic relations because it is not clear from a study of *STP 187* (**1**), or even the earlier works (**8,17,18,19**) upon which the final ASTM recommendation is based, how some of the constants—particularly r_0 and n—are obtained.

In our tests:

$E = 14.1 \times 10^6$ psi for tinned, annealed ETP copper wire,

t = the times of interest, namely 3000 and 30,000 hr,

σ_0 = the initial stress (in our tests, the initial stresses of interest were 5000, 6000, 8000, 10,000, and 12,000 psi), and

$b = 1$.

The constant n was determined from a series of step-down creep tests which are summarized in Fig. 12. This figure shows the relation between residual stress and time for tinned annealed ETP copper wire while the specimen is kept within constant elongation parameters. For example, an initial load equivalent to 25,000 psi stress was ap-

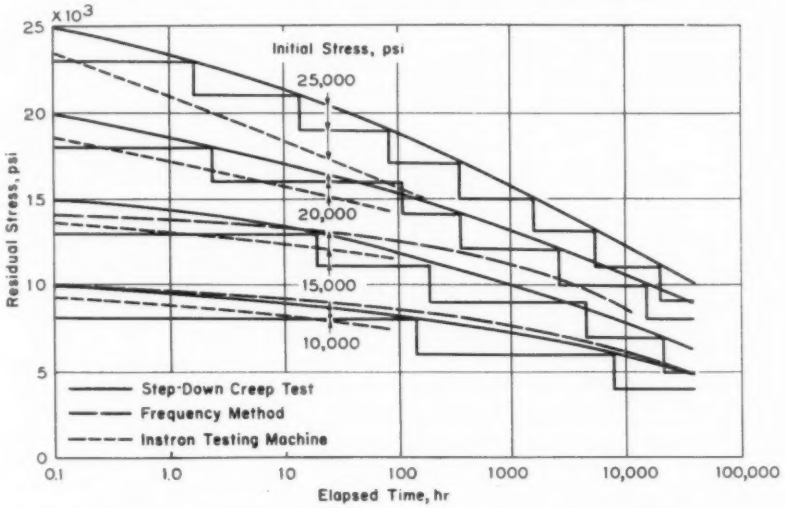

Fig. 12.—Comparison of stress-relaxation curves for tinned annealed ETP copper wire obtained by three different methods; nominal diameter 0.0201 in.

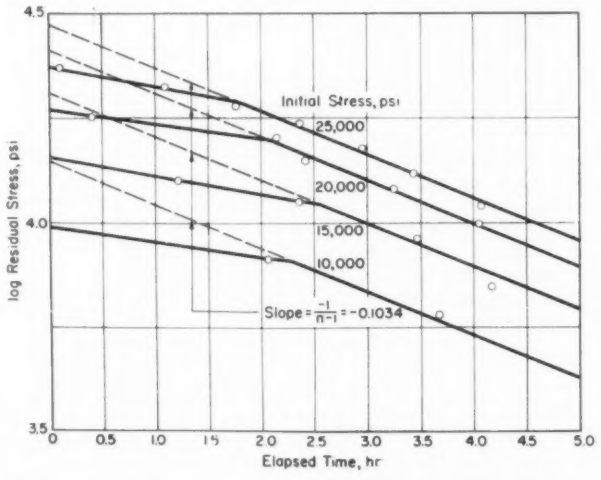

Fig. 13.—Residual stress versus time relations from step-down creep tests on tinned annealed ETP copper wire; tested at 80 to 85 F; nominal diameter 0.0201 in.

plied to the first pair of specimens and the instantaneous strain was observed to be 0.001773. An increment of load equivalent to 2000 psi was immediately removed, as a result of which the strain was observed to decrease to 0.001638—a net change of 0.000135. Now, for perfectly elastic behavior the decrease in strain should be equivalent to decrease in stress/modulus of elasticity, that is, $2000/(14.1 \times 10^6) = 0.000142$. Since the instantaneous recovery was observed to be only 0.000135, it may be assumed that the remainder, namely 0.000007, represents the reproducibility of the strain measurements. (It might also be due to internal strain rearrangements which would not be observed on an external strain gage.)

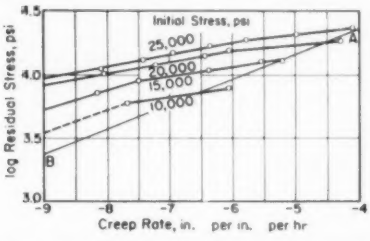

Fig. 14.—Residual stress-rate curves from step-down creep tests on tinned annealed ETP copper wire; tested at 80 to 85 F; nominal diameter 0.0201 in.

The residual stress of 23,000 psi was allowed to remain on the specimen until the total strain again reached a value of 0.001773. In the case of the specimens originally stressed to 25,000 psi, the average time required for the specimens to creep to a total strain of 0.001773 was 1.68 hr. The second increment of load (2000 psi stress) was then removed, as a result of which the strain again decreased. This time, under a residual stress of 21,000 psi an average of 14.0 hr was required for the strain to reach its upper limiting parameter. This step-down creep was continued as shown in Fig. 12 until the tests were discontinued after some 42,000 hr. Duplicate tests were made at each of the test stresses.

Average creep rates can be computed from the time values shown in Fig. 12 and the corresponding observed values of strain for any stress increment.

Figure 13 is a replot of the residual stress-elapsed time values for the step-down creep tests shown in Fig. 12 for various initial stresses. For elapsed times in excess of 100 hr such a log-log plot yields a series of straight lines whose slope is $-[1/(n-1)]$ where n is the stress-rate index required in the solution of Eq 11. In the example cited the lines are parallel but this condition may not always prevail.

To obtain the value of r_0 required for the solution of Eq 11 it is assumed that for each creep stress and time there is an unique creep rate. Thus, if the time to produce a given strain under a given stress can be observed, the average creep rate can be calculated. Such rates can be computed from the data presented in Fig. 12 for the step-down creep tests and the two strain parameters. An analysis of this type yields average rate data for the first, the second, and succeeding test periods for each specimen in the step-down creep tests. A log-log plot of these rate values against the corresponding residual stress values yields a series of curves for each initial stress level such as those shown in Fig. 14.

A line AB connecting the points representing the average creep rates for the first step shown in Fig. 12 for each stress level gives the relation between stress σ_0 and r_0. The r_0 values and the corresponding stress values—which in this case are selected as equivalent to the initial stresses—are required for the solution of Eq 11. The reciprocal slope of the various stress-rate curves should, according to *STP 187* (1) be equivalent to n, whose value was previously determined from the curves shown in Fig. 13. This appears to be correct within the limits of experimental error. The value for n computed from the curves shown in Fig. 13 is approximately 11 (10.67) whereas the slope of the second portion of the individual curves shown in Fig. 14 is approximately 12 (11.75).

Using the values for n and r_0 obtained as described in the preceding paragraphs, values of residual stress were computed from Eq 11 for elapsed times of 3000 and 30,000 hr. These values are shown in Table I.

TABLE I. — COMPARISON OF OBSERVED AND CALCULATED RESIDUAL STRESSES AS OBTAINED FROM EQ 11 FOR TINNED ANNEALED ETP COPPER WIRE.

(Calculations Based Upon Step-Down Creep Tests)

Initial Stress, psi	Time, hr	Residual Stress, psi	
		Observed	Calculated
5 000	3 000	4000	4400
	30 000	3100	3400
6 000	3 000	4600	4900
	30 000	3500	3800
8 000	3 000	5300	5800
	30 000	4600	4500
10 000	3 000	7000	6500
	30 000	5300	5200
12 000	3 000	8400	7400
	30 000	6900	5800

From Table I it is evident that the use of Eq 11 to compute residual stresses or stress-relaxation curves yields results which are in fair agreement with observed values. The calculated values are high by approximately 10 per cent at an initial stress of 5000 psi, while at stresses above 8000 psi the reverse is true. At 12,000 psi the calculated values are low by as much as 16 per cent. This is not objectionable since it provides some factor of safety.

Conclusions

1. Equipment has been designed and built which permits the determination of stress-relaxation in tension. This has been demonstrated to be suitable for specimens having diameters up to 0.2 in. The method is suitable for use at normal, subnormal, or elevated temperatures.

2. Useful engineering data on stress-relaxation in compression can be obtained on a large number of specimens in a minimum of time by employing a limited creep test device such as that developed by the authors.

3. Stress-relaxation curves on the ETP copper wire tested by the authors show no indication of becoming asymptotic with the time axis, even after 30,000 hr. For other materials, such as Copperweld, Dumet, and the nickel and nickel alloy wires, stress-relaxation appears to be negligible after 1000 to 3000 hr although measurements made after 16,500 hr show that stress-relaxation has not yet ceased.

4. Extrapolation of a semilogarithmic plot of stress-relaxation data for a period of 1000 hr obtained in the frequency test was in good agreement with subsequently observed data.

5. A review of the literature indicates that differences in the mechanisms of stress-relaxation and creep at constant load (stress) make the reliability of functional relations developed for obtaining values of one from the other questionable. This is particularly true if extrapolation is involved.

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Discussion

Chairman A. C. Webber.[1]—I should like to inquire what you do when the filament or specimen you are testing is a nonconductor. We deal with very few conductors in my field.

Mr. G. R. Gohn (*author*).—Mr. Webber has raised a very interesting question. We have not resolved it as yet. We have the same problem in connection with some of our newer satellites where glass, nylon, or dacron filaments must be used for design, and we have to know something about their stress-relaxation characteristics. So far, all we have been able to do is to make standard step-down creep tests on these materials and calculate the stress-relaxation from such data.

A wire (string) passing through the field of a permanent magnet and driven by an alternating current yields stress-relaxation data only on materials that are conductors. This method will work on magnetic materials as well as on nonmagnetic materials provided that the air gap and driving voltage are increased when the former are tested. If a mechanical oscillator were substituted for the electrical oscillator a technique could be developed for testing nonconductors (11).

Mr. Webber.—Would you dare put a small piece of magnetic material on the center of the vibrating string?

Mr. Gohn.—I don't see why this could not be done. We have not tried it. However, I think the suggestion is well worth considering.

Mr. W. E. Wolstenholme.[2]—The principle of the vibrating-string technique for measuring changes of stress under tension was used by us in work on stress relaxation in high polymers. Results were published in the *Journal of Applied Physics* in 1944. In our instrument, called a "Mechanical Oscillator," a steel wire was vibrated by an air jet. One end of the wire was attached to a lever so that the wire tension could be altered by a chain-amatic system similar to that used on standard analytical balances, but with heavier chains. Rubber specimens were stretched and placed in a rack that mounted on a bar to which the other end of the vibrating wire was attached. The tension in the vibrating steel wire was varied to obtain sympathetic vibration of the stretched rubber samples. Some elementary experiments provided easy conversion of steel wire tension to rubber tension with high accuracy.

Incidentally, in answer to the chairman's question on whether the vibrating-string method could be used in plastics or similar materials, we are now using the same mechanical oscillator slightly modified for testing the stress decay in a polymeric type of film and thread. In production of golf balls, the tension of the elastic thread is maintained within very narrow limits by a similar system while the thread is in motion.

The feature that interests me is that very little has been said about temperature effects. These are very important; the characteristics of stress relaxation curves vary greatly with temperature. In my opinion the thermal dependence of stress relaxation is a dominant characteristic, and the activation energy or distribution of these factors must be determined in order to characterize relaxation effects.

Mr. Gohn.—In our paper we refer to the previous work of Mooney, Wolstenholme, and Villars (11), which I believe is the article Mr. Wolstenholme cited. We were familiar with their use of a mechanical oscillator to drive the test specimen and to check the frequency in a vibrating string. However, for our own use the mechanical oscillator was much too bulky. Since we had only a limited amount of space, we therefore developed the test using the electronic setup.

As far as temperature is concerned, the equipment used is maintained at constant temperature where the allowable range is from 80 to 85 F. Actually, temperature measurements show a range of about ±1 F. For the copper wires, this variation in temperature results in a strain due to differential thermal expansion between the test specimen and the frame which produces an additive stress of about 40 psi; on the Kovar wires the additional stress is about 140 psi. On this basis, for the temperature variations observed, the calculated stress might be in error by ±40 psi in the case of materials having a coefficient of expansion comparable to that of copper and a modulus of around 14×10^6 psi, and about three times this value for materials such as Kovar having a lower coefficient of expansion and a higher modulus of elasticity.

We have not attempted to apply temperature corrections to our data. How-

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[2] Senior Research Scientist, U. S. Rubber Research Center, Wayne, N. J.

ever, we believe that the equations have been developed that could be used for correcting the data reported.

A. G. H. DIETZ[3] (*by letter*).—The authors have performed an admirable service in (1) setting forth the importance of stress-relaxation measurements as clues to the internal structures and internal rearrangements leading to diminution of stress in materials subjected to constant strain; (2) reviewing some of the more important methods of measuring stress-relaxation; (3) describing the theoretical relationships between creep and stress-relaxation; and (4) explaining why the derivation of stress-relaxation data from creep tests is essentially empirical curve-fitting and therefore should be done with caution, especially if extrapolation is involved. The review of theory is most useful to workers in this field, and the results of tests, especially the step-down creep tests and interpretation of the results, are illuminating.

In our plastics research laboratory the early part of the stress-relaxation curve for organic polymers has been found to be quite sensitive to small variations in composition or polymerization processes. This is particularly true of the relaxation occurring in the first few milliseconds; after that the rates of decay may become gradual enough to reduce the sensitivity of the measurements. Small changes in composition or structure of both linear (thermoplastic) and cross-linked (thermosetting or vulcanized) materials have been noted quite clearly.

As the rate of initial straining to the predetermined maximum strain is increased, polymeric materials behave more and more nearly like Newtonian elastic materials. In some instances of highly crystalline linear polymers such as polyethylene, when initial strains are high enough, the material exhibits a nearly perfect elastic-plastic behavior during the initial straining; that is, it is almost perfectly linearly elastic to a definite yield point, then suddenly yields plastically without increase in stress. If it is strained to a predetermined strain level and the strain held constant, relaxation immediately begins and stress decays normally.

It appears to be evident that research in stress-relaxation behavior of materials can yield fruitful insights into the internal structure and behavior of materials.

[3] Professor of Building Engineering, Department of Civil and Sanitary Engineering, Massachusetts Institute of Technology, Cambridge, Mass.

Technical Note

Convenient Way to Find Natural Logarithms Is Especially Useful for True-Strain Values

By Ralph G. Crum[1]

As AN engineer-educator, I have been at times faced with the problem of finding the natural logarithm of a certain number when no table or slide rule was available. Not using these quantities very often, I was embarrassed to find I was often considerably off with my estimates, so I began to use the following scheme for finding natural logarithms: If one plots the curve of $1/x$ versus x for values of x between 1.0 and any desired value, the area under this curve equals ln x. This is clearly seen from the area integral

$$\text{Area} = \int_{x=1}^{x=x} \frac{1}{x}\,dx = \ln \frac{x}{1} = \ln x$$

Even more helpful is the fact that for values of x between 1.0 and 2.0 the hyperbolic curve of x versus $1/x$ is nearly linear and the area is approximately

$$\frac{1}{2}\left(1+\frac{1}{x}\right)\left(x-1\right) = \frac{1}{2}\left(x-\frac{1}{x}\right)$$

A maximum error by this approximation is 8 per cent at $x = 2.0$.

The particular case where I find this most useful is in teaching materials. The equation for true strain at fracture is

$$\epsilon_T = \ln \frac{l_f}{l_o}$$

where:

l_f = gage length at fracture, and
l_o = original gage length.

This equation takes into account the continuously varying gage length during the test. In order to find the maximum value of ϵ_T at fracture, one must take an orginal gage length of zero just at the point of maximum neck. This can only be approximated, but if one assumes that the volume of the metal specimen being tested remains constant during the final stages of the test (or Poisson's Ratio = $\frac{1}{2}$), then

$$A_o l_o = A_f l_f, \qquad \text{or} \qquad \frac{l_f}{l_o} = \frac{A_o}{A_f}$$

$$\epsilon = \ln \frac{A_o}{A_f} = 2 \ln \frac{d_o}{d_f} = \text{approximately } \left(\frac{d_o}{d_f} - \frac{d_f}{d_o}\right)$$

where:

A_o = original area of specimen,
A_f = minimum area of specimen at fracture at the neck,
d_o = original diameter of specimen, and
d_f = minimum diameter of specimen at fracture at neck.

For d_o/d_f to be 2.0 (maximum error = 8 per cent), the specimen would have a very high neck. Actually, for most cases, the error is around 1 per cent. As an example, if $d_o = 0.5$ in. and $d_f = 0.4$ in. $\epsilon_T = \frac{5}{4} - \frac{4}{5} = 0.45$ by the approximation and 0.4462 by tables.

[1] Senior Scientist, Space Systems Operations, Aeronutronic Division, Ford Motor Co., Newport Beach, Calif.

Fracture Toughness Measurements with the Shear-Cracked Specimen

By J. D. MORRISON and J. R. KATTUS

This paper describes an inexpensive, easily prepared fracture-toughness specimen, called the shear-cracked specimen, that has been used in the evaluation of high-strength sheet materials. In direct comparisons made at different laboratories, between three types of fracture-toughness specimens (sharp edge-notched, central fatigue-cracked, and shear-cracked), it was found that the shear-cracked specimen is quite suitable for the evaluation of quench-hardenable and age-hardenable sheet materials. For work-hardenable materials such as the austenitic stainless steels, fatigue-cracked or edge-notched specimens are more suitable. It is believed that, through the use of shear-cracked specimens, laboratories engaged in large-scale evaluation programs involving high-strength low-alloy steels or age-hardenable alloys can reduce their costs considerably.

An article was published recently (1)[1] on fracture testing as applied particularly to the ultrahigh-strength sheet alloys that are presently candidates for use in rocket-motor casings and other critical applications. The first chapter of the article gave the theoretical basis for a method to assess the fracture toughness of sheet materials. The second chapter illustrated the application of the recommended procedure to the evaluation of the effects of temperature on the fracture toughness of several high-strength sheet materials, and the third chapter covered the use of three types of specimens in screening tests on these materials. More recently, another excellent article (2) amplified the fracture-mechanics concept that furnished the basis for the original fracture testing procedure. It also reported new data on the behavior of cracks of subcritical size.

Of the three types of specimens considered for screening use in these articles, two were for use in tension tests. These specimens had either very sharp edge notches or central transverse slits terminating in fatigue cracks. Because both specimen designs required considerable time and expense to prepare, details were also presented on an instrumented bend test that uses a simple, easily prepared sheet specimen (1).

The purpose of this paper is to describe another easily prepared and inexpensive fracture-toughness specimen—the shear-cracked specimen—which was developed about three years ago at Southern Research Inst. and which should be quite useful in large screening programs of certain high-strength sheet materials.

Specimen

The gross geometry of the shear-cracked specimen is similar to that of the central-fatigue-cracked specimen (1).

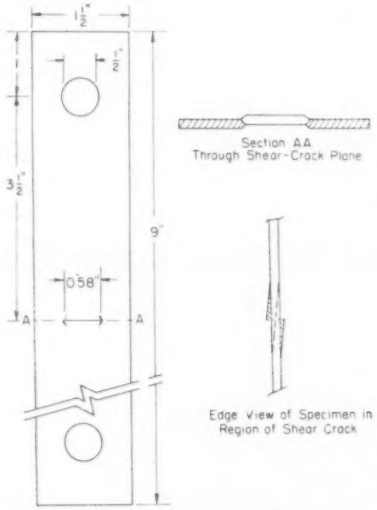

Fig. 1.—Typical shear-cracked specimen.

The dimensional requirements for the fracture-toughness specimen are met with respect to the ratios of width-to-thickness, width-to-length, and crack-length-to-width. A typical shear-cracked specimen is shown in Fig. 1. The shear crack is produced by means of a punch-and-die fixture operating in a small punch press. The opposed offset punches shear through the thickness of the specimen making a central transverse slit, each end of which terminates in a slight tear. The rounded punch ends produce the projecting points in the crack plane of the specimen, as shown in Section AA of Fig. 1.

Punch-and-die fixtures of four sizes which produce shear-crack lengths of approximately 0.20, 0.35, 0.58, and 0.95 in. have been used at Southern Research Inst. This range of punch sizes is suitable for specimens up to 3 in. wide. The smaller punches were used

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[1] The boldface numbers in parentheses refer to the list of references appended to this paper.

J. D. MORRISON received his B.S. from Birmingham-Southern College in 1948 and has since done graduate work in physical chemistry at that school. From 1949 to 1952, he worked in the Department of Metallurgy, Inspection, and Research, at the TCI Division, U. S. Steel Corp. In 1952, he joined the staff of Southern Research Inst., Birmingham, Ala., and has since been engaged in research in physical chemistry and metallurgy.

J. R. KATTUS is a metallurgical engineering graduate of Purdue University. He spent two years in metallurgical research at the U. S. Naval Research Laboratory. Since 1952, he has been head of the Metallurgy Div. at Southern Research Inst., where he has supervised many research projects in the fields of physical and mechanical metallurgy.

for narrow specimens prior to the establishment of the dimension requirements for fracture-toughness specimens by the ASTM committee. In more recent work, specimens 1½ in. wide containing shear-cracks 0.58 in. long have been used for sheet thicknesses from 0.040 to 0.080 in. For sheet thicknesses from 0.080 to 0.125 in., specimens 2.65 in. wide with shear-cracks 0.95 in. long are used.

Specimens of quench-hardenable and age-hardenable materials are shear-cracked in the annealed condition before final hardening treatments. Work-hardenable materials, such as the austenitic stainless steels, have been shear-cracked after severe cold-working treatments that produced hardnesses up to Rockwell hardness C 52, which probably represents the maximum hardness level that can be shear-cracked without excessive damage to the punches.

After the specimens have been blanked out, they can be shear-cracked in the punch press at the rate of about 30 per min.

Fracture-Toughness Evaluation

In the evaluations made with shear-cracked specimens, the crack-propagation properties are obtained for each material over a range of temperatures from about −200 to 600 F or higher depending upon the nature of the material being evaluated (**3**). The quantities usually determined are the net fracture stress (or notch strength) and the percentage of shear in the fracture surface. These terms are defined in reference (**1**). A loading rate is usually used so that fracture occurs within about 2 min. Occasionally much more rapid loading rates have been used when it was desired to simulate special environmental conditions.

Tensile yield strength and ultimate strength are obtained in the same temperature range with "smooth" specimens of each material for comparison with crack-propagation properties.

As in the case for fatigue-cracked and sharp edge-notched specimens, the fracture-toughness parameter, K_{c3}, may be calculated for shear-cracked specimens from maximum load data, initial crack-length measurements, and percentage-of-shear values. By means of measurements of critical crack lengths, K_{c1} values may be also obtained.

The results of an evaluation of 0.064 in. thick 4335 V (AMS 6434) steel sheet, oil-quenched from 1620 F and tempered at 400 F, are shown in Fig. 2. This evaluation is fairly typical for the low-alloy steels. Shear-cracked specimens 1.5 in. in over-all width with shear-crack lengths of 0.58 in. were used. An abrupt decrease in net fracture stress occurred at about −125 F,

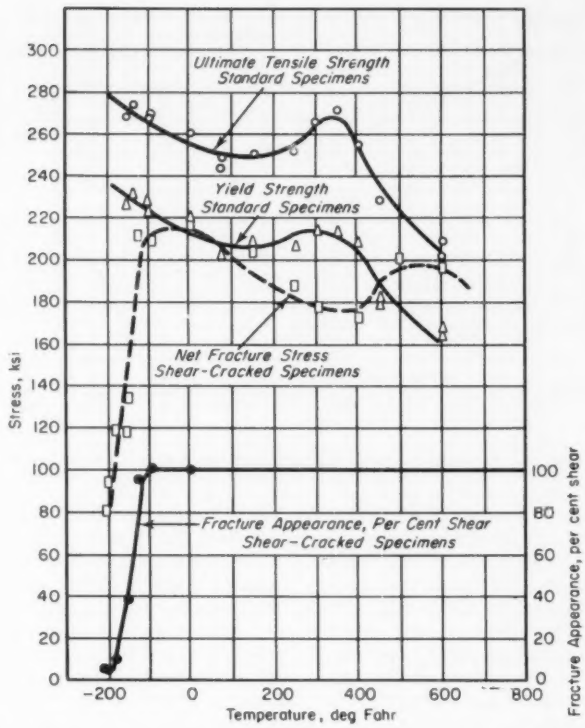

Fig. 2.—Effect of temperature on tensile and fracture properties of heat-treated longitudinal specimens of AMS 6434 steel sheet.

coinciding with a sharp reduction in percentage of shear. Thus, based on the crack-propagation properties, the brittle-ductile transition temperature for this steel was −125 F. In Fig. 3, the fracture surfaces of the shear-cracked specimens are shown. In this photograph, the relative width of the region of flat tensile (brittle) fracture can be seen in the surfaces of the specimens fractured at very low temperatures. The tensile-strength maximum at 350 F (Fig. 2), and the lowered net fracture stress at this temperature, are believed to be associated with strain aging. Such tensile-strength maxima and ductility minima have been reported for various steels at temperatures near 350 F or

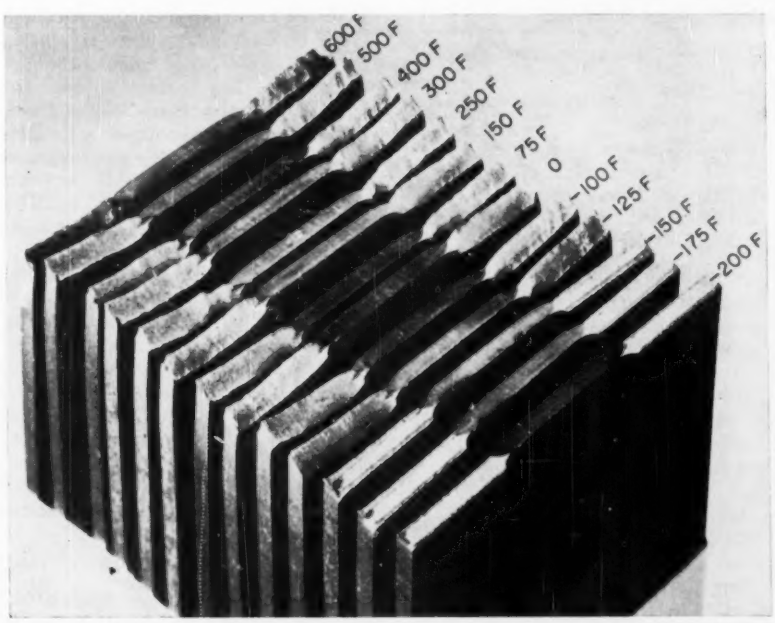

Fig. 3.—Fracture surfaces of shear-cracked specimens of AMS 6434 steel. (Numbers are test temperatures in degrees F.)

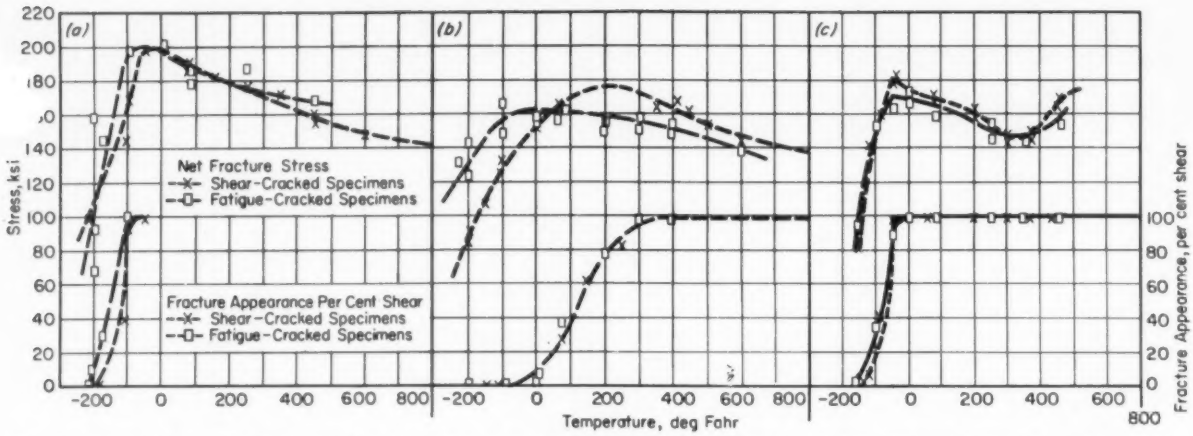

Fig. 4.—Comparison of crack-propagation properties at various temperatures obtained with two different types of specimens. (*a*) AM 350 (SCT-850), (*b*) 17-7 PH (TH-1050), (*c*) AISI 4130 (T 825).

higher, depending upon composition. These effects apparently are largely a function of the content of interstitial elements, particularly carbon and nitrogen. It is interesting that a minimum in fracture toughness at about 350 F for ultrahigh-strength steel sheet has been reported by other investigators, who evaluated these materials by means of an instrumented bend test (**4**).

Comparison of Data

Because of the evident attractiveness of the shear-cracked specimens from the standpoints of ease of production and uniformity of notch dimensions, an attempt was made to establish its validity by a direct comparison with other types of fracture-toughness specimens whenever possible. Comparisons between shear-cracked and fatigue-cracked specimens have been made at Southern Research Inst. using the following sheet materials:

AM 350 (semi-austenitic stainless steel),
17-7 PH (precipitation-hardening stainless steel),
AISI 4130 (low-alloy steel),
7075T-6 (aluminum alloy),
7079T-6 (aluminum alloy),
2024T-86 (aluminum alloy), and
X2020T-6 (aluminum alloy).

In the comparative work with the steels, a normal, rather slow loading rate was used over a temperature range from about −200 to 600 F or higher. For the aluminum alloys, rather special conditions were used to simulate certain service conditions to which aircraft structures may be exposed. These conditions necessitated the use of a temperature range from 75 to 400 F and a very rapid loading rate, such that fracture occurred within 0.1 sec after the initiation of loading.

Thus, the comparative data were obtained under a variety of conditions for a variety of sheet materials. The results of these comparative experiments are shown in Figs. 4 and 5. It is felt that, with the exception of the net-fracture-stress data for the 17-7 PH material (Fig. 4(*b*)), the agreement between the two types of specimens is quite good.

A comparison of shear-cracked and fatigue-cracked specimens of two low-alloy steels has been reported by Srawley (**5**). In his work, Srawley used shear-cracked specimens prepared with the "rounded-end" punches at Southern Research Inst. and also some specimens shear-cracked with "chamfered punches" at the Naval Research Laboratory. The results obtained in the limited comparative work at NRL showed a good correlation between shear-cracked and fatigue-cracked specimens for the materials investigated.

In addition to the two comparative studies cited, a more extensive joint effort has been undertaken by the NASA Lewis Research Center and the Naval Research Laboratory to compare three types of fracture-toughness specimens prepared from three different sheet materials. The specimen types compared were: the sharp edge-notched (NASA), the central notched or fatigue-cracked (NRL), and the shear-cracked (SRI). The materials used in the work were: an H-11 steel, an all-beta titanium alloy, and a 70 per cent cold-reduced type 301 stainless steel.

Some of the data obtained in the joint comparative study have been reported (**6,7**). From the standpoint of the shear-cracked specimen, the data already reported indicate that for the H-11 steel, this specimen is quite suitable for fracture-toughness evaluations, being as sensitive as the fatigue-cracked specimen; for the cold-worked stainless steel, the shear-cracked specimen was less sensitive than either the fatigue-cracked or the sharp edge-notched specimens.

Flattening Shear-Cracked Specimens

Because of the lesser sensitivity shown by the shear-cracked specimen for the cold-worked stainless steel (**7**), some means of increasing the sensitivity of the specimen was sought, so that it would be suitable for fracture-toughness evaluations of all classes of high-strength sheet materials. It had been suggested by Srawley (**5**) that an effort should be made to remove the "kink" in the sheet plane caused by the action of the shear-punches. Therefore, a preliminary comparison was made to evaluate the effects of the discontinuities in the sheet plane. Shear-cracked specimens of AISI 4340 steel sheet were prepared, and some of these specimens were flattened in a press, to remove the kink in the sheet plane and the protrusions caused by the punches. The specimens were then hardened and tempered at 400 F. Net-fracture-stress data and percentage of shear were obtained for the two types of shear-cracked specimens over a temperature range from −200 to about 500 F (**3**). These data are shown in Fig. 6, where it can be seen that the flattened specimens were slightly more embrittled than the unflattened specimens.

Since flattening apparently imparted greater sensitivity to the shear-cracked specimen, the comparative study was extended to include several stainless steel alloys, cold-worked at ambient and low temperatures ("zerolled") to high strength levels. A comparison was made of the notch strength of these materials as obtained with flattened shear-cracked specimens and with sharp edge-notched specimens ($K_t = 18$). The comparative data are shown in Table I. The various alloys used in this study—types 301, 304L, 310, and 330—and the rolling conditions used, resulted in the production of sheet materials representing a range of structures from largely ferritic to untransformed, heavily cold-worked austenitic. The comparative notch-strength data obtained lead to the conclusions that, for the stable 310 330 alloys and the moderately cold-worked (partially transformed) 304L

TABLE I.—COMPARISON OF ROOM-TEMPERATURE NOTCH STRENGTH[a] OF COLD-WORKED[b] STAINLESS STEEL ALLOYS OBTAINED WITH FLATTENED SHEAR-CRACKED SPECIMENS AND WITH EDGE-NOTCHED SPECIMENS.[c]

Alloy	Condition	Net Fracture Stress, Flattened Shear-Cracked Specimens, ksi	Notch Strength, Edge-Notched Specimens, ksi
310	Reduced 60 per cent at 80 F	166.0	194.0
330	Reduced 40 per cent at −40 F	147.5	164.0
301	Reduced 60 per cent at 32 F	231.5	249.0
304L	Reduced 40 per cent at −40 F	221.0	226.0
304L	Reduced 40 per cent at −320 F	245.0	218.0
304L	Reduced 80 per cent at 32 F	195.0	135.0

[a] Values reported are averages of two or three individual tests.
[b] Longitudinal specimens from strips cold-rolled as indicated and subsequently stress-relieved at 800 F for 24 hr.
[c] NASA-type notched specimen, K_t = 18; 1 in. in over-all width; 30 per cent notch depth; notch root radius nominally 0.0005 in. (0.0007 in. max).

and 301 alloys, the flattened shear-cracked specimen is equal or superior in sensitivity to the sharp edge-notched specimen. But for the more completely transformed 304L material, the flattened shear-cracked specimen is somewhat less sensitive.

Conclusions

On the basis of the comparative data thus far obtained, the following general statements are made.

1. For the laboratory making a limited number of fracture-toughness evaluations on a wide variety of sheet materials including work-hardenable stainless steels, it would no doubt be better to use fatigue-cracked specimens or sharp edge-notched specimens, assuming that the necessary fatigue equipment or machining facilities are available.

2. For the laboratory screening large numbers of quench-hardenable and age-hardenable sheet alloys and evaluating the effects of several variables, such as various heat treatments on these materials, the shear-cracked specimen would be of considerable economic advantage. If it were possible to standardize on no more than two specimen widths, say 1½ and 3 in., only two punch-and-die fixtures would be required. Two of these fixtures could be constructed by a good machine shop for a total cost of about $600.

Acknowledgments:

Much of the data reported in this paper was obtained in the course of work sponsored by the Bureau of Naval Weapons. We are grateful to the International Nickel Co. for permission to publish the fracture-toughness data on the "zerolled" stainless steel alloys.

It is a pleasure to acknowledge the helpful suggestions and cooperation of J. E. Srawley of the Naval Research Laboratory and W. F. Brown of the NASA Lewis Research Center, who made it possible to include the shear-cracked specimen in the comparative specimen-evaluation program.

The assistance of M. A. Campbell and W. L. Rogers, who performed much of the experimental work, is gratefully acknowledged.

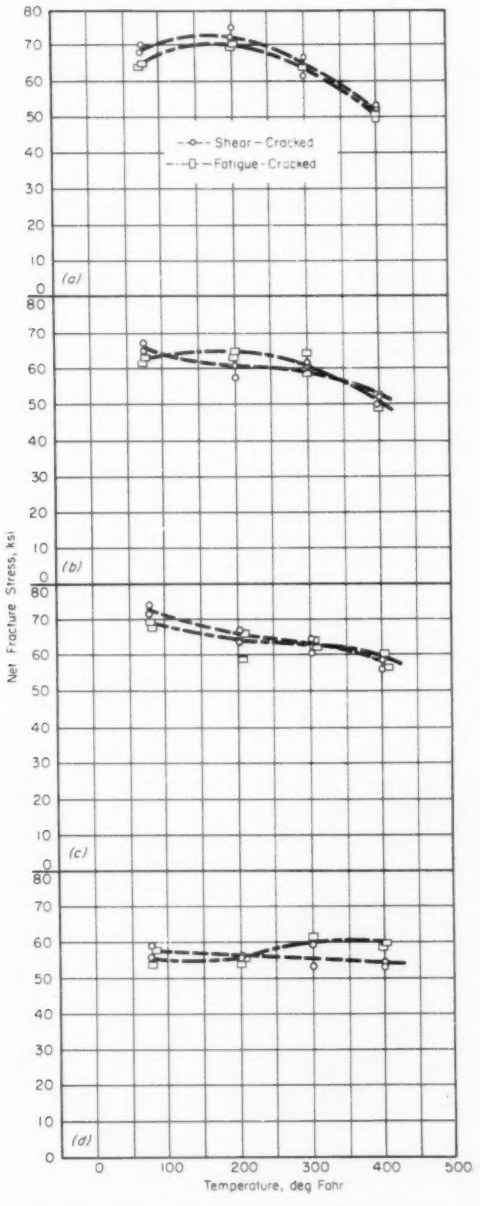

Fig. 5.—Comparison of crack-propagation properties at various temperatures obtained with two different types of aluminum alloy specimens. (*a*) 7075-T6, (*b*) 7079-T6, (*c*) 2024-T86, (*d*) X2020-T6.

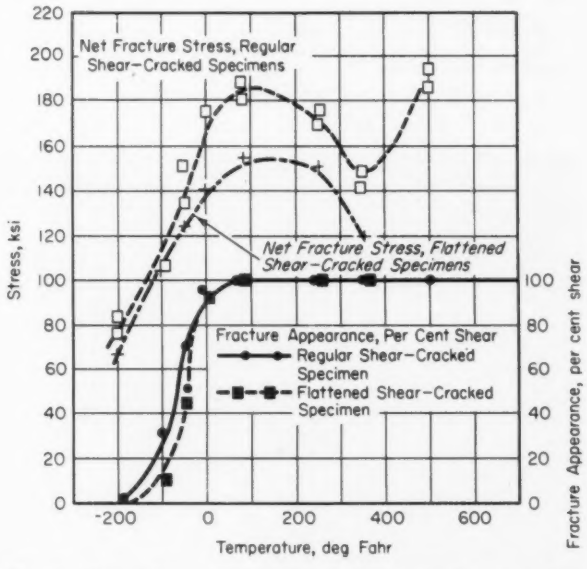
Net Fracture Stress, Regular Shear-Cracked Specimens
Net Fracture Stress, Flattened Shear-Cracked Specimens
Fracture Appearance, Per Cent Shear
Regular Shear-Cracked Specimen
Flattened Shear-Cracked Specimen
Stress, ksi
Fracture Appearance, per cent shear
Temperature, deg Fahr

Fig. 6.—Comparison of crack-propagation properties at various temperatures obtained with normal shear-cracked and flattened shear-cracked specimens of quenched and tempered AISI 4340 (T 400) steel sheet.

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(1) "Fracture Testing of High-Strength Sheet Materials," A Report of a Special ASTM Committee, ASTM Bulletin, No. 243, Jan., pp. 29–40; No. 244, Feb., pp. 18–28 (1960).

(2) "The Slow Growth and Rapid Propagation of Cracks," Second ASTM Special Committee Report, *Materials Research & Standards*, Vol. 1, No. 5, pp. 389–393, (May, 1961).

(3) J. D. Morrison and J. R. Kattus, "An Investigation of Methods for Determining the Crack-Propagation Resistance of High Strength Alloys," Summary Technical Report to the Bureau of Naval Weapons, Contract NOas 60-6040c, March 7, 1961.

(4) R. McPhee, K. E. Muszar, G. R. Sippel, and G. L. Vonnegut, "Instrumented Bend Tests Applied to Pressure Vessel Reliability," Presented at the Seventh Sagamore Conference on Ordnance Materials Research, Raquette Lake, N. Y., August 16–19, 1960.

(5) J. E. Srawley, "Crack Propagation Tests of High Strength Sheet Materials; Comparison of Shear-Cracked With Fatigue-Cracked Specimens," *Memorandum Report 1081*, U. S. Naval Research Laboratory, July, 1960.

(6) W. F. Brown, Jr., "Mechanical Screening Tests for Sheet Alloys," Presented at the Seventh Sagamore Conference on Ordnance Materials Research, Raquette Lake, N. Y., August 16–19, 1960.

(7) A. G. Holms, "NRL-NASA-SRI Cooperative Study of High Strength Sheet Specimens Intended for Measuring Design Values of Crack Toughness," Prepared discussion presented at the Seventh Sagamore Conference on Ordnance Materials Research, Raquette Lake, N. Y., August 16–19, 1960.

Discussion of a Paper on a Fatigue Test for Printed Wiring Boards and Through Connections[1]

Mr. C. R. Smith.[2]—The authors do not include data representing tests on boards with lead wires attached to the eyelets. Would that have materially affected the fatigue results? The tests seem to have been made on open eyelets.

Mr. G. R. Gohn (*author*).—The tests on boards with the lead wires in the through connections is the second phase of the investigation. This is part of a larger statistical study in which several producers' products are being evaluated, and we had to divide the test into two parts. In the first series of tests we evaluated boards without any lead wires soldered to through connections using a Latin-square arrangement to facilitate statistical analysis of the data. The second phase of the program will include the addition of lead wires in the through connections. These will be soldered in place, as is normally the case. The data from these tests will then be compared with those presented in this paper.

Mr. R. F. Brodrick.[3]—I should like to remark about the apparent disagreement with Coffin's slope of plastic strain versus cycles to failure. Since in the present case the geometry is somewhat complicated and a joint between dissimilar materials is involved, the true plastic strain at the point of failure may differ considerably from the nominal value. If the true plastic strain values were known and used, it is quite conceivable that the slope might agree most closely with that obtained by Coffin.

Mr. A. Fox (*author*).—I should like to point out that the control samples for which we have presented data had no through connections. These were just plain copper strips along the length of the test specimen, and hence the strain in these conductors should be the same as it is in a standard fatigue specimen, since there is no stress concentration. However, the slope of the curve for the data from these tests plotted as recommended by Coffin was approximately $\frac{1}{3}$. However, this discrepancy may be due to the bonding between the copper and the plastic substrate.

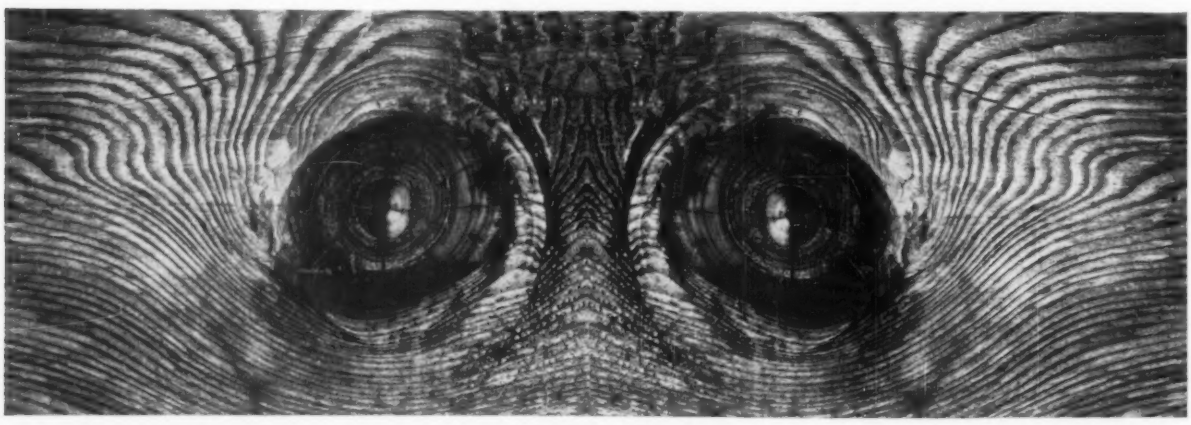
Mr. Brodrick.—Yes, you have the dissimilar materials with different elastic moduli, etc.

Mr. Fox.—That is right.

[1] "A Fatigue Test for Printed Boards and Through Connections," by G. R. Gohn and A. Fox, *Materials Research & Standards* (formerly ASTM Bulletin) Vol. 1, No. 9, Sept., 1961, p. 711.

[2] Design Specialist, Convair, Div., General Dynamics Corp., San Diego, Calif.

[3] Senior Project Engineer, Lessells and Associates, Inc., Boston, Mass.



A Wooden Stare

Twelfth ASTM Photographic Exhibit. Third prize, general class, black-and-white—materials. M. W. Girard, American Bitumuls and Asphalt Co., Emeryville, Calif.

The Seventh Approximation

A New Pedological Scheme of Soil Classification

By RICHARD L. HANDY[1]

CLASSIFICATION IS THE first handmaiden of science. Perhaps more precisely it should be called the wet nurse of science, later becoming its consort, in some sciences being elevated to queen supreme. Without classification, knowledge would be factual chaos, difficult to retain and impossible to understand, like women, horse racing, and social studies.[2]

Actually, classification on the basis of need is one of our lower instincts, predating science by about the same amount that eyesight predates ophthalmology. For example, even the lowly worm will turn when he learns his two most pertinent categories of everything—can I eat it or will it eat me? In the case of parasitic worms the answers to both questions are yes, and the classification breaks down. Another instinctive classification is by sex, but the worm cannot make head nor tail of that either, being a bilateral opposed. Scientific classification relies not so much on use or general appearance as on objective observations and attention to detail.

At this point we interrupt with a brief comment on the purported subject of this article,[3] which is soils. The various engineering classifications of soils are rather closely allied with use. Or we can look more kindly and mumble that engineering soil classifications are based on properties which have engineering pertinence. As already implied, a use classification may be totally inept if the use should change. For example, a soil classification that works like a marvel for concocting a granular road base may be of only passing interest when strength comes from a chemical additive such as lime or portland cement.[4]

A hidden goal in classification is to provide something to revise, and soil scientists in the U. S. Department of Agriculture have been revising. Revision of the soil classification has been uniquely implemented with a number of "Approximations" submitted to soil scientists the world over for comments and revisions. The new pedological soil classification is currently in the Seventh Approximation, and in another three years or so should be fairly complete.

Most soil engineers will feel sorely wounded by all this, for it is only rather recently that we have become familiar with what the soil scientists were up to 20 years ago. At the present rate of acceptance the present revision may take a couple of centuries to assimilate. Let us first review.

> "The Entisols are those soils, exclusive of Vertisols, that have a plaggen horizon or that have no diagnostic horizon other than an ochric or anthropic epipedon, an albic horizon, an argic horizon, or, if the *N* value exceeds 0.5 in all horizons between 20 and 50 cm, a histic epipedon . . ."
>
> *The Seventh Approximation*, Chapter 8, "Entisols."

The Russian School

Any history of science always refers to this school or that school, further illustrating our exaggerated regard for degrees in education. In the 1870's a Russian scientist named V. V. Dokuchaiev created some rather enduring fallout; Dokuchaiev noted that the character of any soil appeared to be the result of five factors of soil formation: climate, organisms (especially vegetation), parent rock, relief, and time. Vary one factor such as climate, vegetation, or parent rock, and you find a different soil.

The heart of Dokuchaiev's soil classification is the "normal" or "zonal" soil, which primarily reflects climate and vegetation, that is, geographic zone. A comrade named Sibertsev then suggested the concepts of "intrazonal" and "azonal" soils. Intrazonal soils primarily reflect some local factor such as excess water or carbonates (which relate to relief and parent material). A particular intrazonal soil may occur in several geographic zones. Similarly, an azonal soil crosses zonal boundaries, and is essentially unweathered parent material.

The Russian classification based on genetic factors has been periodically modified, kicked out, hauled back, and barely tolerated by numerous later workers. The Americans G. N. Coffey and later C. F. Marbut maintained that a proper classification should rely on soil characteristics rather than on all these questionable inferences regarding origin. Marbut came closest to putting this goal into practice, but his classification had some serious loopholes that were not resolved. The Russian influence is shown in the USDA classification of 1938 modified in 1949, although division of orders into suborders, great soil groups, and ultimately into the basic soil-mapping unit, the soil series, follows a biological scheme. Relations of the

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[1] Associate Professor of Civil Engineering, Iowa State University of Science and Technology, Ames, Iowa.

[2] Classification lets the chaos be orgar ized.

[3] Anything goes in a feature article.

[4] As a matter of fact, Portland Cement Assn. data show that cement requirements for soil-cement tend to correlate better with agricultural soil series than with engineering soil classes.

zonal soils to climate are illustrated in Fig. 1.

Although each great soil group is defined on the basis of properties, the 1938–1949 classification is essentially genetic, and genesis invariably brings arguments. Some perfectly respectable soils have been left out because nobody knows which is the dominant factor. Furthermore, the Russo-American classification leaves no room for soil intergrades, which balks us liberals who look for answers in compromise. Nor is there provision for changes in soils due to cultivation or social climate, which provokes the Soviets who want it known that everything becomes better under Communism. Therefore, a new classification was needed—one based on soil properties (which relate to soil genesis) and not so closely oriented to prejudices regarding virginity. Any reasonable man knows one must love her for what she is, and not for what she used to be, even if her profile does look a shambles.

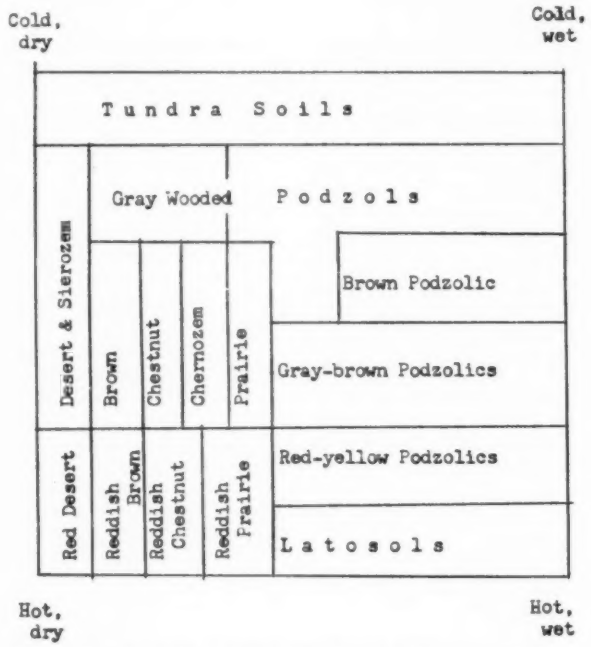


Fig. 1.—Idealized relationship of zonal great soil groups to climate.

The Soil Profile

Speaking of profiles, the most striking characteristic of soil is the tendency to form a layer cake, each layer being dubbed a "horizon." This is recognized in the vernacular in the terms topsoil and subsoil. Topsoil brings to mind dark, loamy material suited for raising tulips, wheat, corn, onions, and cool cash from the soil bank. Subsoil is the hard or sticky stuff located underneath, where it functions as a reservoir for moisture and for the dear-departed. Dirt is soil out of place, as on shoes, carpets, little boys, or pages of a two-bit novel. To a soil scientist or engineer dirt is a dirty word. It is not used.

A horizon.—Topsoil is more formally designated the A horizon. The A horizon may be either a dark-colored A_1, dark because of organic matter, or it may be a light-colored A_2, light because of loss of clay, iron, and aluminum. The A_2 is characteristic of podzols and podzolic soils, podzol coming from folk Russian meaning ashy soil. An A_3 is a transitional horizon to the underlying subsoil. The A horizon may be a foot or so thick, more or less, somewhat and depending.

B horizon.—Subsoil is better termed the B horizon, and is even more variable than the A. It may be an accumulation zone of clay, iron, aluminum, humus, or a combination of these, or it may be a residual concentration of such materials. It may differ from other horizons mainly in color, but it usually shows a different structure such as tendency to break into small angular blocks or vertically oriented prisms. The zone of maximum whatever is called the B_2; B_1 and B_3 are upper and lower transitions.

Underneath the B is the C horizon, which usually displays some weathering but is below the zone of normal biological activity except for a few petroleum gophers. Salts such as calcium carbonate or gypsum may accumulate, making a C_{ca} or C_{ca}.

Other subscripts denote special topics; for example an A_p is a crazy mixed-up A horizon due to plowing. A subscript m means cemented, so a C_{cam} is a C horizon carbonate cemented into a hardpan, or duripan. The subscript x, as a B_x or C_x, indicates a "fragipan," or literally brittle pan, in other words a hard layer of high density. The x signifies what is known about its origin.

Progressive Education

Every soils man—engineer, scientist, shovel superintendent, or whatever, must dig these ABC's. Unfortunately the letters are not very completely descriptive; for example, they say nothing of the variability of different B horizons.

Courtesy William Johnson, USDA.

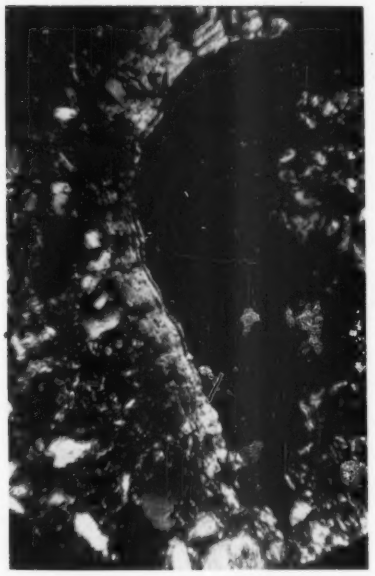
Fig. 2.—Gray Wooded soil (Typaltalf) on a Manitoba lake clay. The A horizon is white (A_2) and overlies a clayey, somewhat blocky B. Below 24 in. is the C horizon.

Therefore, a few supplemental terms have been defined in the Approximations. The terms are for diagnostic horizons pertinent to the new classification, and the names smack strongly of the new soil classes. Actually when one understands what these are about, the rest, like sin, is almost easy.

Pedon.—First we come head-on with the pedon, which rhymes. The pedon is considered to be the smallest volume which satisfactorily represents a soil, and is analogous to the unit cell in crystallography. The pedon is thus a hexagonal prism ordinarily 1 to 10 sq m in area and with a rather vague lower limit.

Epipedon.—The epipedon (overpedon) is loosely the A horizon plus any of the B darkened by organic matter. In the new classification six kinds of epipedon are recognized, from Molly to Manure. Only 1, 3, 4, and 5 (asterisk) are common in the U. S.:

*1. Mollic (= soft) epipedon, a thick, dark, organic A_1 horizon, Ca^{++} saturated, feels nice and loamy. Where the tall corn grows.



Courtesy Klaus Flach, USDA.

Fig. 3.—Clay skin (white banded area) enclosing a soil pore (black) as seen under a polarized light microscope.

2. Anthropic (man-ipulated) epipedon. Same as mollic but high in phosphate due to long cultivation and fertilization.

*3. Umbric (= shady or dark) epipedon. Same as mollic but H^+ saturated. An acid soil.

*4. Histic (= tissue) epipedon, a peaty or mucky horizon less than a foot thick, normally water-saturated.

*5. Ochric (= pale) epipedon, a light-colored A_2 or albic (white) horizon.

6. Plaggen (= meadow) epipedon, an A_p accumulated to more than 20 in. thick. Explanation for the thick A is long continued manuring.

To summarize, an A_1 is mollic, and A_2 is ochric, and a plaggen is B.S., M.S., and Ph.D.[5]

Subsurface New Words

*1. An argillic (= clayey) horizon is a B-horizon significantly enriched with clay from above. The soil may break into blocks or "peds" that must show "clay skins," which are thin coatings of oriented clay formed around soil pores, grains, or peds, giving a shiny appearance. Clay skins are most readily seen and verified under a microscope. Clay skinning has recently become a favorite outdoor and indoor sport among U. S. soil scientists.

2. Agric horizon. Same as argillic but modified from long cultivation.

*3. Natric (= sodium) horizon, same as argillic but with columnar or prismatic structure and over 15 per cent exchangeable sodium. Sodium disperses the clay, making for sticky problems. Southwest U. S.

*4. Spodic (= ashy) horizon, a B-horizon enriched with humus or sesquioxides such as Fe_2O_3 or both. No clay enrichment, no structure, no clay skins. May be cemented into a hard layer called an ortstein. Podzols.

*5. Cambic (= changed) horizon, a mildly weathered horizon between the A and the C with original rock structure gone. Little or no structure, no clay skins. Does not form in sands.

*6. Oxic (= oxide) horizon, a concentration of sesquioxides and kaolin clays due to removal of silica by strong weathering. Grows pineapple.

[5] This joke has peculiar academic franchise. M.S. = more of same; Ph.D. = piled higher and deeper.

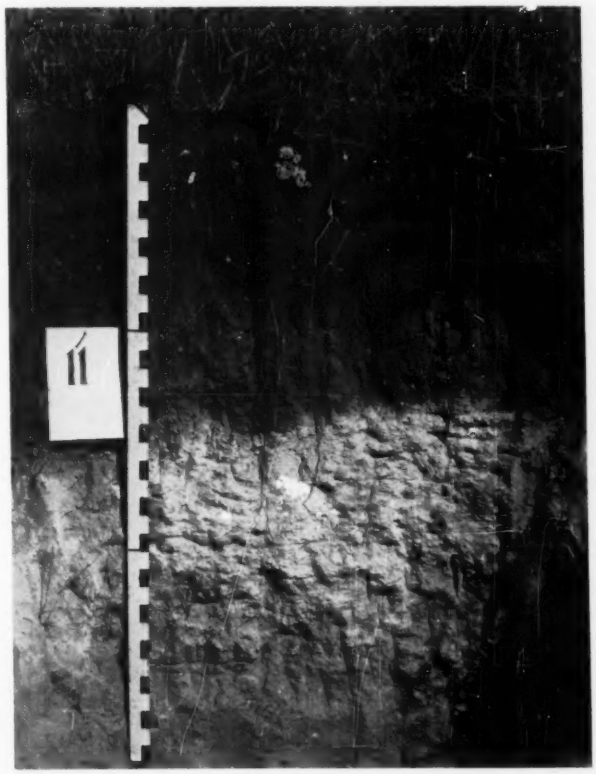
TABLE 1.—PRESENT SOIL ORDERS AND APPROXIMATE EQUIVALENTS IN REVISED CLASSIFICATION OF BALDWIN, KELLOGG, THORP, AND SMITH, 1938–1949.

Order	Meaning	Approximate Equivalents
1. . . Entisols	Recent soil	Azonal soils, and some Low Humic Gley soils
2. . . Vertisols	Inversion soil	Grumusols
3. . . Inceptisols	Inception soil	Ando, Sol Brun Acide, some Brown Forest, Low Humic Gley, and Humic Gley soils
4. . . Aridisols	Arid soil	Desert, Reddish Desert, Sierozem, Solonchak, some Brown and Reddish Brown soils, and associated Solonetz
5. . . Mollisols	Mollic Epipedon	Chestnut, Chernozem, Brunizem (Prairie), Rendzinas, some Brown, Brown Forest, and associated Solonetz and Humic Gley soils
6. . . Spodonsol	Podzol (ashy)	Podzols, Brown Podzolic soils, and Ground-Water Podzols
7. . . Alfisols	Pedalfer (Al-Fe) soil	Gray-Brown Podzolic, Gray Wooded soils, Noncalcic Brown soils, Degraded Chernozem, and associated Planosols and some Half-Bog soils
8. . . Ultisols	Ultimate soil	Red-Yellow Podzolic soils, Reddish-Brown Lateritic soils of the U. S., and associated Planosols and Half-Bog soils
9. . . Oxisols	Oxide soil	Laterite soils, Latosols
10. . . Histosols	Tissue soil	Bog soils

Orders

One of the first inspirational things man did when he invented language was execute some orders, or was it order some executions? Anyway, we have a new language and a whole world to talk about, so let us sound off: Entisol, Vertisol, Inceptisol, Parasol! The first three are new names for soil orders. The last keeps off the sun.

Names of the soil orders are supposed to suggest vaguely the kind of soil. For



Courtesy William Johnson, USDA.

Fig. 4.—Chernozem ABC, North Dakota. The A is black, rooty, a mollic epipedon. The B is dark but weak, a cambic horizon. The white is a C_{ca}. New classification is Haplaltoll.

example, Entisols are the exceptionally unweathered rec*ent* soils, formerly called Azonal. Vertisols include Black Cotton Soils or Grumusols, characterized by inversion, or vertical mixing due to sloughing into desiccation cracks. Our ultrarich prairie soils come under Mollisols, meaning they have a mollic epipedon (organic, calcium-saturated A-horizon). Alfisol looks like it might be rather good for alfalfa, but that would be a use classification so that's out. Actually it refers to "Pedalfer," an old tag for aluminum-iron soils.

Courtesy Guy D. Smith, USDA.

Fig. 5.—Inversion in the Vertisols tips fence posts and eucalyptus trees, South Australia.

The newly coined names are mainly from Latin and Greek, with a few German, French, and nonsense syllables thrown in. Therefore it helps to know the languages, and know your nonsense as well.

Whereas the old orders were genetic, the new ones are defined on the basis of measurable soil properties, such as thickness and kind of horizons, clay content, cation-exchange capacity, and conductivity of an extract. Particularly pertinent to engineers is the *N*-value, indicative of bearing capacity. *N* equals natural moisture content minus two, divided by per cent clay, plus three times the per cent organic matter. An *N*-value above 0.5 means tread softly or you'll sink.

Suborders

As any pfc can tell you, each order gives rise to numerous suborders which can drive one to distraction. Whereas orders were three syllables (Ent-i-sol), suborders go by two. Furthermore, the last syllable indicates the order: Aquent (Aqu/ent = aqueous recent) is the hydromorphic suborder of Entisols. Similarly, there are Aqu*ert* (hydromorphic *Vert*isol), Aqu*ept* (Incept*i*sol), Aqu*oll* (*Moll*isol), Aqu*od* (Spod*o*sol), Aqu*alf* (*Alf*isol), and Aqu*ult* (*Ult*isol). A major overhaul from the old classification is that hydromorphic soils fall under six suborders. Other suborders of Entisols are *Psamm*ent (sandy), *Ust*ent (hot climate), and *Ud*ent (humid climate).

Great Groups

There are so many great groups we'll not be able to call them all, but there are the New York Yankees, Elks, Young Republicans, ASTM, Laurel and Hardy, and the Mills Brothers, to name a few. Great groups of soils further divide the suborders, and are indicated by a third syllable tagged on the front. You may notice that names are beginning to have a rather foreign sound suggesting high Eskimo. Actually the resulting great group name is as easy as 1–2–3, only it's 3–2–1. For example, in Arctic cold the Aquent becomes a *Cry*aquent, Cry meaning cold. Or an Aquoll (hydromorphic Mollisol) with an argillic or clayey horizon is an *Arg*aquoll.

Subgroups

Stop us if you've heard this before, but Albollic Argaquoll! What we mean is the soil is not just an ordinary Argaquoll (see above), in which case it would be an Orthic Argaquoll; it is Albollic, Albollic denoting the subgroup and indicating an intergrade character with an Alboll—whatever that is. If we take it apart we see Alb, meaning white horizon, and oll, meaning Mollisol. Starting at the back, an Albollic Argaquoll should have a dark A horizon (oll), wet conditions (aqu), an argillic or clayey B horizon (arg), and least of all a weak albic or A_2 horizon probably just above the B.

Finale

Beneath the subgroups remain as always the families and the basic mapping unit, the soil series. These still are named after a locality such as Ames, Boone, or Dubuque.

And that, friends, is the new pedological classification system in a nutshell and ready for roasting.

TABLE II.—GLOSSARY OF FORMATIVE ELEMENTS FOR ORDERS, SUBORDERS, GREAT GROUPS, AND SUBGROUPS.

acr	most weathered	ert	inversion	orth(ic)	true
agr	agric horizon	ept	inception	ox	oxide
alb	albic horizon	ferr	iron	phan	allophane
alf	Pedalfer (Al-Fe)	frag	fragipan	plac	thin pan
alt	high (cool)	fragloss	= frag + gloss	plag	plaggen horizon
and	Ando (volcanic ash)	gloss	tongued	plint	plinthite (brick)
anthr	man-modified	grum	crumby	psamm	sandy
agu	water-modified	hal	salty	quarz	quartz
arg	argillic horizon	hapl	min. horizon	rend	on limestone
brun	dark brown	hum	humus	rhod	dark red
calc	calcic horizon	hydr	wet	ruptic	int. hor. intergrade
camb	cambic horizon	id	arid	sal	salic horizon
crust	crusting	ist	tissue	thapto	in paleosol
cry	cold	lithic	on rock	therm	warm
crypt	deep horizon	maz	massive	typ	typical
cumulic	accumulating	nadur	= natr + dur	ud	humid
dur	duripan	natr	natric horizon	ult	strongly weathered
dystr	low-base sat.	ochr	ochric horizon	umbr	umbric horizon
eutr	high-base sat.	od	spodic horizon	ust	dry, hot
ent	recent	oll	mollic horizon	verm	animal mixing

Acknowledgments:

The author extends his thanks to Dr. Guy D. Smith, Director, Soil Survey Investigations, USDA, and Dr. Frank F. Riecken, professor of agronomy, Iowa State University of Science and Technology, for their help and indulgence. Soil engineering research at Iowa State is being carried on under several projects of the Iowa Highway Research Board under sponsorship of the Iowa State Highway Commission

Corrosiveness of Various Atmospheres

Report of Task Force of Subcommittee VII on Weather of Committee B-3 on Corrosion of Nonferrous Metals and Alloys

In 1948 Subcommittee VII of Committee B-3 on Nonferrous Metals and Alloys appointed a Subgroup on Corrosiveness of Various Atmospheric Test Sites as Measured by Specimens of Steel and Zinc. The report of this subgroup[1] aroused so much interest that a new program was begun in 1960 to determine the relative corrosivity of test sites in England, the Canal Zone, additional sites in Canada and the United States, and eventually the Philippines. The results of the first year of exposure of steel and zinc specimens are discussed here.

As in the previous work, the losses in the rural atmosphere at State College, Pa., were taken as unity, and the relative corrosiveness at each of the other locations is given in Table I as a fraction or a multiple of unity. For comparison, the relative ratings at the locations included in the first program are given also.

Inspection of the data reveals that:

1. Steel has a greater range of losses than zinc.
2. Steel lost over 2000 times as much weight during one year at the 80-ft site at Kure Beach, N. C., as at Norman Wells, N.W.T. (65°17′N-126°51′W), Canada (just below the Artic Circle). The ratio for zinc was 1:40.
3. The corrosion of both steel and zinc was less in the tropical jungle site of the Panama Canal Zone (Location No. 3 in Table I) than at State College (No. 9), but more than in the colder, dryer, and probably equally free-of-pollution site at Saskatoon, Sask., Canada (No. 2).
4. The relative corrosiveness of the 11 sites designated as "marine" depends upon how much sea-water spray is deposited upon the specimens.
5. The corrosiveness of test locations on roofs was less than would be expected if the specimens had been on test racks on the ground, probably because on roofs dew wets the specimens later and dries off sooner than on the ground.
6. The great variations in corrosiveness show that some maps purporting to give such factors are not sufficiently detailed to indicate the wide local differences that may be caused by prevailing wind direction relative to the major source of pollution.

Respectfully submitted,
C. P. Larrabee, chief research engineer—corrosion prevention, United States Steel Corp.
O. B. Ellis, senior research engineer, Armco Steel Corp.

[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 59, p. 183 (1959).

TABLE I.—CORROSIVENESS OF ATMOSPHERES AT 37 TEST SITES RELATIVE TO THAT AT STATE COLLEGE, PA. (TAKEN AS UNITY). BASED ON LOSSES OF TWO 4 BY 6-IN. SPECIMENS.

		Steel				Zinc			
		Grams		1960–1961	1948–1956[b]	Grams		1960–1961	1948–1956[b]
Location	Type of Atmosphere	Avg Loss	Range[a]	Rating	Rating	Avg Loss	Range[a]	Rating	Rating
1. Norman Wells, N.W.T.	Rural	0.1	0.0	0.02	0.03	0.052	0.001	0.2	0.4
2. Saskatoon, Sask.	Rural	1.4	0.1	0.2	0.6	0.074	0.001	0.2	0.6
3. Fort Clayton, C. Z.	Tropical jungle	2.8	0.1	0.4	...	0.266	0.018	0.8	...
4. Rocky Point, B.C.	Marine	4.6	0.1	0.7	0.5	0.110	0.009	0.3	0.4
5. Potter County, Pa.	Rural	5.2	0.1	0.8	...	0.250	0.029	0.7	...
6. Detroit, Mich.(R)[c]	Urban	5.9	0.1	0.9	...	0.270	0.015	0.8	...
7. Ottawa, Ont.	Rural	5.8	0.0	0.9	...	0.233	0.002	0.7	1.3
8. Morenci, Mich.	Rural	6.4	0.2	1.0	...	0.261	0.014	0.8	...
9. State College, Pa.	Rural	6.4	0.1	1.0	1.0	0.334	0.035	1.0	1.0
10. York Redoubt, N.S.	Marine	7.4	0.3	1.2	1.5	0.371	0.008	1.1	2.1
11. Montreal, Que. (R)[c]	Industrial	8.3	0.0	1.3	1.5	0.492	0.033	1.5	3.0
12. Middletown, Ohio	Semi-industrial	8.8	0.1	1.4	1.2	0.323	0.010	1.0	1.0
13. New Hampshire Coast, N.H.	Marine	9.4	0.3	1.5	...	0.458	0.032	1.4	...
14. South Bend, Pa.	Semi-rural	10.5	0.1	1.6	1.5	0.396	0.014	1.2	1.6
15. Columbus, Ohio (R)[c]	Urban	10.9	0.1	1.7	...	0.468	0.009	1.4	...
16. New Cristobal, C.Z. (R)[c]	Tropical marine	11.1	0.0	1.7	...	0.740	0.003	2.2	...
17. Pittsburgh, Pa. (R)[c]	Industrial	11.4	1.2	1.8	...	0.512	0.002	1.5	...
18. London (Battersea), England(R)[c]	Industrial	12.7	0.0	2.0	...	0.409	0.004	1.2	...
19. Trail, B.C.	Industrial	13.2	0.1	2.1	1.4	0.501	0.004	1.5	...
20. Miraflores, C.Z.	Tropical urban	13.2	0.1	2.1	...	0.334	0.008	1.0	...
21. Research Center, Pittsburgh, Pa.	Semi-industrial	14.0	0.2	2.2	...	0.488	0.006	1.5	...
22. Daytona Beach, Fla.	Marine	14.3	1.2	2.2	7.1	0.418	0.017	1.3	2.1
23. Bethlehem, Pa.	Industrial	15.2	0.2	2.4	...	0.262	0.003	0.8	...
24. Cleveland, Ohio	Industrial	15.5	0.1	2.4	...	0.485	0.016	1.5	...
25. Newark, N.J.	Industrial	16.8	0.2	2.6	...	0.779	0.002	2.3	...
26. Brazos River, Tex.	Marine	17.1	0.3	2.7	...	0.466	0.001	1.4	...
27. Bayonne, N.J.	Industrial	21.6	0.5	3.4	...	1.020	0.026	3.1	...
28. Kure Beach (800-ft site), N.C.	Marine	23.2	3.4	3.6	2.0	0.640	0.000	1.9	1.4
29. Pilsey Island, England	Marine	25.8	0.8	4.0	...	1.058	0.016	3.2	...
30. East Chicago, Ind.	Industrial	33.5	0.0	5.2	...		STOLEN		...
31. London (Stratford), England	Industrial	41.3	1.6	6.5	...	1.608	0.019	4.8	...
32. Halifax, N.S. (Fed. Bldg.)	Marine industrial	46.9	2.7	7.3	3.8	2.913	0.096	8.7	22
33. Point Reyes, Calif.	Marine	61.0	0.6	9.5	1.8	0.338	0.017	1.0	1.4
34. Dungeness, England	Marine	97.2	5.1	15	...	0.768	0.001	2.3	...
35. Galeta Point Beach, C.Z.	Tropical marine	117.3	[d]	18	..	2.577	[d]	7.7	...
36. Widnes, England	Industrial	119.5	1.3	19	...	2.716	0.038	8.1	...
37. Kure Beach (80-ft site), N.C.	Marine	210.1	12.4	33	13	2.114	0.071	6.4	5.7

[a] Plus or minus. [b] Table XXII, Report of Committee B-3 (Appendix II), *Proceedings*, Am. Soc. Testing Mats., Vol. 59, p. 200 (1959). [c] Exposure made on roof of building. [d] Only one specimen exposed at this location.

ASTM Standards in the ASME Boiler and Pressure Vessel Code

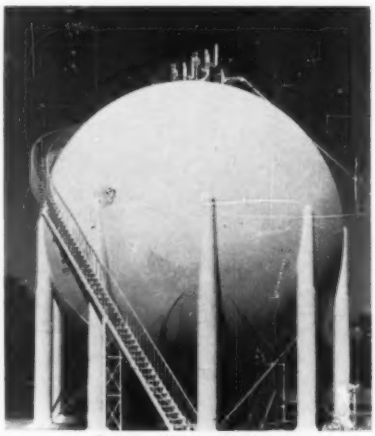
By E. M. KLOEBLEN[1]

When was the last time you heard about a boiler explosion? Here is how two great societies have cooperated to build an enviable safety record.

THE BOILER AND Pressure Vessel Code of The American Society of Mechanical Engineers is a widely accepted standard which has contributed much to the safety of boilers and pressure vessels. Although many economies in investment and operating costs may also be credited to the code, it is primarily a safety construction code, born of the deaths, injuries, and widespread property damage from steam boiler explosions in the 19th and early 20th centuries.

Advent of Steam Brings Need for Control

The steam engine began to replace water power more than 150 years ago, and the energy stored in the steam boiler soon demonstrated its highly destructive force when improperly controlled. As early as 1817 the need for establishing rules for the maintenance and operation of boilers was recognized by a joint committee of the Councils of the City of Philadelphia when they urged adoption of state laws covering maintenance and operation of boilers, installation of safety valves, and regular inspection. In 1849 a law was in effect in Massachusetts requiring the use of fusible plugs, and in 1880 provision for inspection and the power to condemn were part of the Massachusetts ordinance. Massachusetts also was in the vanguard of states recognizing special inspectors; their boiler law included such recognition in 1893. While rules for the maintenance and operation of boilers were also adopted by New York City, Chicago, and Detroit before the turn of the century, the first construction code for steam boilers was adopted in Massachusetts in 1907, followed shortly by the State of Ohio.



Courtesy Chicago Bridge and Iron Co.

UNFIRED PRESSURE VESSEL

Liquid butane storage vessel built in conformance with the ASME Code for Unfired Pressure Vessels.

The developments that led the Council of ASME in 1911 to appoint a committee to prepare a construction code for boilers were carefully documented in a series of articles in *Mechanical Engineering* in 1952 and 1953 by the late Prof. Arthur M. Greene, Jr. Here, too, are recorded the early difficulties in getting agreement of all parties and in obtaining acceptance of the first code by the ASME Council. Known as the 1914 edition of "Rules for the Construction of Stationary Boilers and for Allowable Working Pressures," it was adopted in the spring of 1915 by the Council of ASME.

ASME Turns to ASTM for Materials Specs

Ten specifications for boiler-plate steel, boiler-rivet steel, bars, castings, and the like covered 30 of the 87 pages devoted to new installations. These specifications were identical to or similar to those of the ASTM. Thus began the coordination of the materials specifications of the boiler code and the ASTM specifications.

The wisdom of the progenitors of the 1914 code in patterning their materials specifications after those already finding general acceptance through ASTM was proved in public hearings in December, 1916, when only a minimum of adverse comment was heard on the materials specifications parts of the code. Further bonding the ties of these organizations at this time was the appointment of conferring groups. Four representatives from ASME joined three from ASTM and representatives from users, manufacturers, and steel fabricators during 1917 on questions of materials specifications and their manner of presentation in the 1918 edition of the code.

Cooperation between the two groups was well established when welding rules were being written between 1919 and 1924. Specifications for flange quality, firebox, and structural quality steel for welding appeared during this period. The 1924 edition of the code contained ten specifications completely in agreement with those of ASTM and four that were substantially the same as their

[1] Safety Codes Dept., Linde Co., Division of Union Carbide Corp, New York, N. Y.

ASTM counterparts. This edition specified two materials for which ASTM had nothing to correspond.

Since then, the code has been expanded from a single section on power and heating boilers to the present eight sections of the 1959 edition, covering the following specific types of equipment, materials specifications, and welding qualifications:

Section	Title
I	Power Boilers
II	Material Specifications
III	Boilers of Locomotives
IV	Low-Pressure Heating Boilers
V	Miniature Boilers
VII	Suggested Rules for Care of Power Boilers
VIII	Unfired Pressure Vessels
IX	Welding Qualifications

Section VI, which covered the suggested rules for the inspection of boilers, was published to furnish a standard procedure that was not strictly within the scope of the code, since it was developing into a construction standard. More appropriately, the National Board of Boiler and Pressure Vessels Inspectors published their "National Board Inspection Code," and Section VI was discontinued.

How the Boiler Code Grows

The Boiler and Pressure Vessel Committee meets six times a year. At each meeting, the committee considers requests for interpretation of the code and rulings for conditions requiring special provisions. Those that are adopted are published in a case interpretation booklet.

Cases are classified as "interpretative," with no change in the intent of existing code rules, or as "special rulings" covering new provisions or new materials. Revisions are made in the code after these cases have proved to be generally acceptable. When a new material is introduced in a "special ruling," it awaits preparation of an ASTM specification if one does not already exist, before it is made a part of Section II.

Revisions are also made in the code without the use of "special ruling" cases. Bringing the code up to date with the latest knowledge in materials, design, fabrication, and inspection methods is a routine procedure handled at these meetings. Twice a year "pink sheet addenda" are issued covering the latest revisions and additions to the sections of the code.

Each new edition brings more ASTM specifications into the code. ASTM specifications for carbon steel and alloy steel forgings as well as for carbon steel castings for valves, flanges, and fittings for high-temperature service appeared first in the 1927 edition. Bearing testimony to this continuous cooperation between ASTM and ASME is the 1959 edition of Section II, "Materials Specifications," with addenda, referring to 135 ASTM specifications—86 "SA" specifications covering ferrous materials and 49 "SB" specifications for nonferrous materials. Further references to 11 ASTM specifications are included in the Case Interpretation Book. The materials specifications section continues to grow as new alloys are developed. The review of new specifications and revisions to the current ones are the responsibility of the Subcommittee on Ferrous and High Temperature Materials and the Subcommittee on Nonferrous Materials. The recommendations of these subcommittees are submitted to the Boiler and Pressure Vessel Committee for action.

When it is necessary to deviate from ASTM specifications, suitable notation is made at the beginning of the specification when published by ASME either as pink sheet addenda or in subsequent editions of Section II. Conversely, ASTM includes a statement on such materials specifications indicating the extent to which they have been adopted for the ASME Boiler and Pressure Vessel Code.

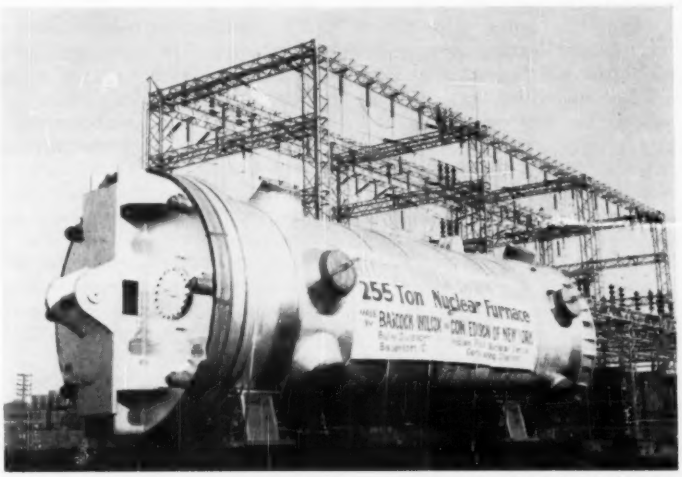
The ASTM system of numbers is retained to identify the code material specification, using an "S" prefix. Thus ASTM plate steel specification A 212 became SA 212 in the code when it was adopted by the Boiler and Pressure Vessel Committee and B 42 for copper pipe became SB 42.

Close Liaison Maintained

The need for close liaison between the ASME and ASTM committees was recognized early in the code work. An ASTM staff member is a member of the ASME materials subcommittees. New ASTM specifications of interest to the Code Committee and revisions to all adopted ASTM specifications are submitted to them for review and adoption. In addition, the Code Committee reviews for adoption other ASTM specifications as need arises for their use.

When adopted by the ASME for code use, specifications published by ASTM indicate on the first page to the right and above the title the corresponding ASME material specification number.

ASME draws its committee memberships from representatives of material producers, designers, fabricators, insurance carriers, legal jurisdictions, and users involved in the safe construction of boilers and pressure vessels. These committees benefit from the experience and background of their members, covering every aspect of boiler and pressure vessel design, fabrication, inspection, and use. They review data on tests and reports of research scientists and engineers gleaned from the laboratories of industry, colleges and universities, and governmental agencies. They prepare rules based on these data and any available service data. In seeking to diversify representation, the ASTM frequently taps the same sources in manning their counterpart materials specification bodies. This often results in a good number of ASME committee members also being active on one or more ASTM groups. Therefore, each aggregation is quite familiar with the work of the other, and in preparing the ASTM specifications they bring their combined knowledge to the task.



Courtesy The Babcock & Wilcox Co.

255-Ton Nuclear Furnace

This is a reactor shell built to an ASME Special Case for Nuclear Service for the Indian Point nuclear electric generating station of the Consolidated Edison Company of New York. View shows temporary top head closure with lifting device for vertical positioning.

Often new materials are developed that justify faster review and action than can be obtained in first seeking an ASTM specification. When test data are adequate, and in order to gain service experience, the Code Committee has a case interpretation procedure that provides for use of new materials upon adoption by the committee and ASME Council. When a code interpretation "special ruling" for a new material is published, revisions are often necessary as experience is gained in the mills and fabricators' plants. After this process indicates acceptance of the provisions of the "special ruling" by all interested parties, the preparation of a specification of the "A" or "B" type is in order. The ASTM staff is officially advised of this recommendation by the Boiler and Pressure Vessel Committee. The "special ruling" case interpretation is annulled when the material is covered by an "SA" or "SB" specification in Section II of the code.

Research Contributors

The research and test programs needed to establish such criteria as limits in acceptance tests, stresses permitted in construction under the code, etc., are often quite extensive and beyond the scope of any one company that may be represented on a committee. In such cases, trade associations of the interested industries may underwrite a project, or one of the branches of the Federal government, such as the National Bureau of Standards, the Army, Navy, or Air Force, will sponsor the required research.

Contributing greatly to this effort to furnish data to the committee is the ASTM-ASME Joint Committee on the Effect of Temperature on the Properties of Metals. Through its fund raising efforts, and the direct support of governmental agencies on some projects, the various panels of the joint committee establish and review test projects, publish papers, conduct symposia, and otherwise supply engineers with the information developed in their projects.

Fusion welding, which has become the most common method for fabricating boilers and pressure vessels, introduced the need for welding rod specifications. It also necessitated new requirements for plate, pipe, tubes, castings, forging, etc., when used in welded construction. Here the Welding Research Council of the Engineering Foundation, financially supported by industry, furnishes much basic test data. The Pressure Vessel Research Committee of the Council has subcommittees supervising projects at various colleges and universities specifically related to welding in pressure vessel design and fabrication. Here, too, the results of the investigations are reviewed by the project committee and published in the bulletins of the Council and in the *Welding Journal*, and presented by the investigators at technical sessions of the American Welding Society and other engineering societies.

Other Cooperating Groups

Other organizations which contribute to the wide acceptance of the code include the National Board of Boiler and Pressure Vessel Inspectors, which is devoted to the uniformity of inspection through the preparation of examinations for inspectors, an inspection code, and approved safety relief valve flow data. The Uniform Boiler and Pressure Vessel Laws Society publishes a model bill for states providing an orderly means for the adoption of the ASME Boiler and Pressure Vessel Code. The National Bureau of Casualty Underwriters publishes a Synopsis of Boiler and Pressure Vessel Laws Rules and Regulations summarizing the requirements of the various states, cities, and Canadian provinces. These organizations, and many industrial concerns interested in the design, manufacture, inspection, maintenance, and use of boilers and pressure vessels constitute the group that keep the ASME code a widely accepted, up-to-date standard.

Widespread Adoption

The ASME Boiler and Pressure Vessel Code has been adopted by 38 states, 35 cities, and 12 Canadian provinces. The most widely adopted portion of the code has been Section I on power boilers. Acceptance of other sections is becoming more widespread as legislative committees receive sound engineering guidance in their consideration of such safety legislation. In transportation, the Interstate Commerce Commission Specifications require ASME Code construction for compressed-gas cargo tanks, which form a part of a highway motor truck or trailer, and for portable tanks, which are skid-mounted. Industry in general, governmental agencies, and the armed forces accept the code as a sound engineering standard and often require compliance even though state or city regulations do not. The Coast Guard and other marine interests keep close contact with the work of the Code Committee and its problems pertinent to marine boiler and pressure vessel construction.

ASME, upon application from qualified manufacturers, issues a certificate of authorization to apply the code symbol on boilers and pressure vessels built in strict compliance with the code. At present there are more than 3000 such authorizations to use symbol stamps.

One of the more recent new applications of the code is for vessels in nuclear service. A series of case interpretations and special rulings have been developed to provide for this service by the Special Committee on Nuclear Power. As experience is gained with the vessels and the cases covering their construction, the rules will be improved and may be expected to become a part of the code proper.

The Future

If past experience can be considered a harbinger of future developments, we may rightly anticipate continued mutual endeavor of both societies toward greater safety through improved engineering, advanced technology, and accurate evaluation of experience and tests, and, incidentally, we may anticipate concomitant economies in investment and operating costs. We can expect other materials to find their way into code construction. The structural metals have been the accepted material for boiler and pressure vessel construction under the code. Recent developments presage increasing applications, particularly in the unfired pressure vessel field, of newly introduced and special application materials such as the reinforced plastics, prestressed concrete, and impervious graphite.

Whether it be metal or plastic or concrete, the ASTM standards can, and no doubt will, provide the material specifications and testing requirements for code construction. Steam power boilers, low-pressure heating boilers, fired and unfired pressure vessels, and the more recent nuclear vessels all require the collective experience and judgment of the materials engineer. Good materials specifications are needed for the fabricator in procuring his materials of construction. The ASME Boiler and Pressure Vessel Committee will continue to look to the ASTM and its materials specifications and test standards for materials control in the Boiler and Pressure Vessel Code.

Legal Guide for Engineers

A NEW DOCUMENT, "Concerning Some Legal Responsibilities in the Practice of Architecture and Engineering and Some Recent Changes in the Contract Documents," is now available from the Engineers Joint Council, 345 E. 47th St., New York 17, N. Y., for $1.

Written by J. R. Clark, of Barnes, Dechert, Price, Myers and Roads, Attorneys at Law, Philadelphia, Pa., the 24-page booklet is based upon a report developed by the EJC-AIA Liaison Committee. It discusses the problems of liability in the practice of the design professions, reviews recent changes in AIA contract documentation, and points up areas of possible liability.

Measuring the Temperature Susceptibility of Asphalt Bitumens

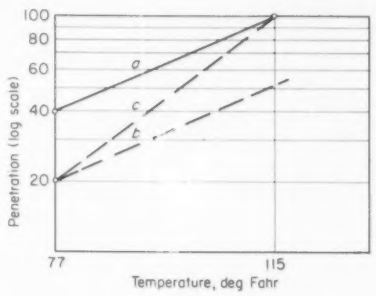
Prepared by Task Force 5 of ASTM Committee D-8, Subcommittee XV on Rheological Properties

SUBCOMMITTEE XV of ASTM Committee D-8 on Bituminous Materials for Roofing, Waterproofing, and Related Building or Industrial Uses has been investigating fundamental test methods to better define the properties of the bitumens and bitumen products covered by ASTM methods and specifications coming under Committee D-8 jurisdiction. One major bitumen property affecting its adaptability for most uses is its consistency—especially the consistency at temperatures within the working or service range. The penetration test (ASTM Method D 5 – 52)[1] is usually used to measure this property of asphaltic materials. Changes in the penetration values at different test temperatures serve to define the change in consistency with temperature, which is called the "temperature susceptibility." The purpose is to ensure that the bitumen will not be too brittle at low temperatures nor too soft at elevated temperatures for the intended service.

For asphaltic bitumens, consistency as measured by the penetrometer is not a linear function of temperature. Therefore susceptibility on such a scale varies with temperature. Another relationship is now recommended so that susceptibility defined in terms of this function is a constant for all temperatures. The procedure is still based on measurements made with the penetrometer. Although penetration is not a fundamental measurement of consistency, the simplicity of the method and its wide use by industry justify its adoption until a rapid, more fundamental measurement of consistency becomes available.

Present Methods Are Indefinite

Present product specifications limit the temperature susceptibility in an indirect manner. Usually the consistency at 77 F is specified within certain limits of penetration. Then a limit is placed on the minimum allowable penetration at 32 F and a maximum allowable at 115 F. This is at best a rough empirical control of temperature susceptibility for two reasons. First, the penetrations at the different temperatures are obtained at conditions that do not permit direct comparison of results because the loading and duration of test differ. For example:



SPECIFICATION:
Penetration at 77 F (100 g, 5 sec) = 20 to 40.
Penetration at 115 F (50 g, 5 sec) = 100 max.

Fig. 1.—Variation in temperature susceptibility according to present system.

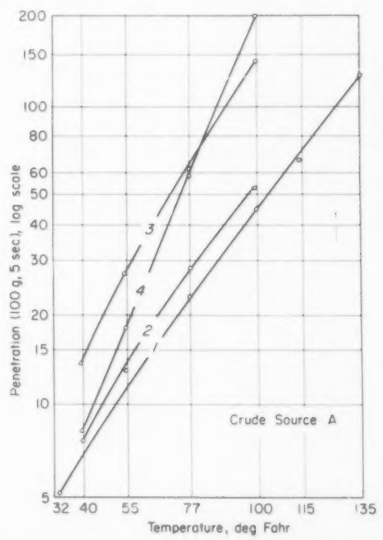


Fig. 2.—Penetration-temperature relationships for asphalts made by different processing methods from crude source A. (Numbers on lines correspond to asphalt identifications in Table I.)

[1] Method of Test for Penetration of Bituminous Materials (D 5 – 52), 1958 Book of ASTM Standards, Part 4.

Penetration at	Load, g	Time, sec
77 F	100	5
32 F	200	60
115 F	50	5

Second, specifications allow some leeway in the basic grade designation (penetration 77 F) in order to permit latitude during manufacture and to allow for the error in the test method. However, there can be a variation in temperature susceptibility with the level of penetration at 77 F, and this is not compensated for in present specifications. Figure 1 shows how this applies to a current specification which limits the penetration at 77 F to a range of 20 to 40 and imposes an upper limit of 100 on the penetration at 115 F. The susceptibility, as reflected in the slope of the line relating the penetration 77 F to the penetration 115 F can vary from a value of *a* to a value of *c* even though the material meets the broad specification. Obviously, a better method would be desirable.

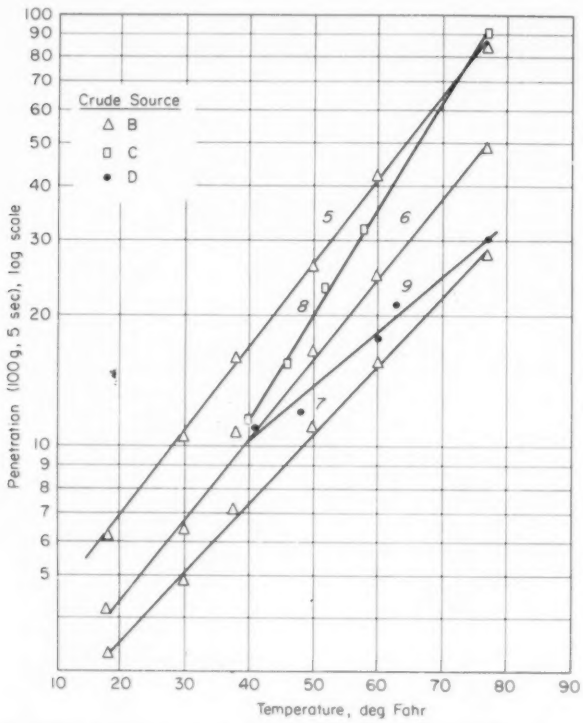


Fig. 3.—Penetration-temperature relationship for asphalts from different crude sources. (Numbers correspond to asphalt identifications in Table I.)

TABLE I.—ASPHALT PENETRATION VERSUS TEMPERATURE.[a]
(Needle Load, 100 g for 5 sec)
Method D 5-52

	Asphalt			
	No. 1	No. 2	No. 3	No. 4
Softening point, deg Fahr	185	180	133	122
Penetration at 32 F	5	...	...	...
40 F	...	7.5	13.5	8
55 F	...	13	27.5	18
77 F	23	28.5	60	58
100 F	45	54	141	201
115 F	66	...	...	...
135 F	126	...	...	...
Ratio: P 100/P 77	1.96	1.90	2.35	3.46
Susceptibility index[b]	1.27	1.21	1.61	2.34

	No. 5	No. 6	No. 7
Softening point, deg Fahr	121	141	159
Penetration at 18 F	6.3	4.2	3.3
30 F	10.5	6.5	4.9
38 F	16.0	10.7	7.1
50 F	26.1	16.6	10.9
60 F	42.4	24.7	15.5
77 F	83.6	49.2	27.7
Ratio: P 77/P 54[c]	2.66	2.67	2.33
Susceptibility index[b]	1.85	1.85	1.60

	No. 8		No. 9
Softening point, deg Fahr	115		181
Penetration at 40 F	11.4	Penetration at 41 F	11.0
46 F	15.5	48 F	12.0
52 F	23.0	60 F	17.9
58 F	31.7	63 F	21.3
77 F	90.0	77 F	30.0
Ratio: P 77/P 54[c]	3.6		1.97
Susceptibility index[b]	2.42		1.28

[a] All asphalts air-blown products except No. 4.
[b] From Table II.
[c] Values obtained from Fig. 3.

Several Procedures Have Been Suggested

Many procedures have been suggested for defining the temperature susceptibility using values obtained with the ASTM penetrometer. A partial listing of these is given in references (1) to (7).[2] Other investigators have suggested susceptibility factors or indices based on high-temperature viscosity determinations as related to the penetration values, softening point versus penetration relationships, etc. (9–12). After a complete review of these methods and, in some instances, actual laboratory comparisons, the most direct route seemed to be to use the relationships established between the penetration value and the amount of load, duration of load application, and the test temperature. For example, with constant load and time of test the relationship is:

$$\log_{10} P = A + BT \quad \ldots\ldots (1)$$

where:

P = penetration,
T = temperature,
A and B = constants for a given type and origin of asphalt.

Lewis and Welborn (6) used this relationship to define the temperature susceptibility of paving asphalts. Previously Bencowitz and Boe (4) considered that a correction factor would be necessary in this case, making the relationship:

$$\log_{10} (P - C) = A + BT \quad \ldots\ldots (2)$$

A study of their data showed that the additional constant C was occasionally required only when penetrations below 10 were encountered. Later, Huet (7) used the simple relationship, Eq 1, on a variety of straight reduced and slightly air-blown paving asphalts. His work

(*Continued on p. 1004*)

[2] The boldface numbers in parentheses refer to the list of references appended to this paper.

1962 PHOTOGRAPHIC EXHIBIT

with sections on Photomicrography, Electron Micrography and Metallography

American Society for Testing and Materials

STATLER HILTON HOTEL . . . NEW YORK, N.Y. . . . JUNE 24 TO 29

During the 65th Annual Meeting of the Society

Photographic Theme

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On behalf of the committee in charge, it is our pleasure to invite all of those interested and eligible, to take part in the 1962 ASTM Technical Photographic Exhibit which will have the theme Materials, Processing, Testing, and Research. Many are acquainted with the attractive and successful displays in past years, and we hope to exceed that success in 1962. Photographs featuring apparatus, instruments, processing techniques, testing, standards, and related items are especially desired. Photographs of a unique or unusual application of materials are welcome, also those featuring the human element.

You are urged to study the information and conditions of entry and to prepare now to exhibit appropriate prints of your work. The committee is particularly interested in having entries from college students, especially in the fields of photomicrography and electron micrography; and those who are in touch with college students are urged to bring the student section of the exhibit to the attention of likely exhibitors.

Additional application forms will be sent on request.

Photographic Exhibit Committee
1962 Annual Meeting

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1962 ASTM Photographic Exhibit

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   (c) color transparencies
3. Electron micrographs

Entry No. *	(Title (10-word max.—Please typewrite or print clearly))	Class

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PHOTOS—DO NOT BEND

From: .....

To

American Society for Testing and Materials
1962 ASTM Photograph Exhibit
1916 Race Street
Philadelphia 3, Pa.

Contents—Photographs.

Postmaster: This parcel may be opened for postal inspection if necessary. Return postage guaranteed.

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INFORMATION AND CONDITIONS OF ENTRY

Participation and eligibility

Any photograph related to the theme and taken by an ASTM member, an employee of a member company, or a registered student in a college, university or technical institute is eligible.

Classes

Entries are solicitied in the following clases:

1. General
   (a) Black and white or monochrome
   (b) Color prints
   (c) Color transparencies
2. Photomicrographs
   (a) Black and white
   (b) Color prints
   (c) Color transparencies
3. Electron micrographs

The class in which a print is entered must be marked on the back of the mount and shown on the entry form.

Number of prints

No limit in number. All contestants are encouraged to submit every print considered eligible under the rules of the exhibit.

Mounts and identification

Photographs other than transparencies and Polaroid - Land photographs must be mounted on 16- by 20-inch mounts. Photographs made with Polaroid-Land Cameras may be mounted on 8- by 10½-inch mounts. All mounts shall be white or buff salon type. Dry mounting is suggested.

On the back of each mount should appear the title, class, and the photographer's name and address corresponding with the data given on the entry form. Color transparencies must be properly identified. No written or printed material should appear on the print or front of the mount; the committee after judging will affix in uniform style the title as given by the photographer, the photographer's name, and company.

Basis of Judging

Photographs in each classification will be judged on: (1) how well the photograph tells the story, (2) the importance of the subject matter, and (3) the photographic excellence. Awards in the form of ribbons will be made for first, second, and third places and for honorable mention. However, if in the opinion of the judges there are insufficient entries in a class conforming to the standard expected of prize-winners, one or more awards in that class may be omitted.

The Committee reserves the right to reject any photographs and entries submitted. The decisions of the judges will be final.

Responsibility

Reasonable care will be taken, but the Society or Committee is not responsible for loss or damage to the entries or shipping cases. Special shipping cases should be clearly identified if the contestants wish to have them returned. Standard fibreboard mailing cases are easily kept track of, but wooden boxes, flats, etc., often are so damaged that reuse is not feasible.

Materials Research & Standards reproduction

It is understood that permission to reproduce photograph in the *ASTM Materials Research & Standards* is granted for pictures submitted. This may necessitate holding the photographs for 6 to 10 months after the Exhibit.

Shipment

All photographs shall be shipped to: 1962 ASTM Photographic Exhibit, ASTM, 1916 Race Street, Philadelphia 3, Pa. Use the attached label. It is advisable to ship your entries in a salon case.

All student entries should be properly identified.

Photomicrographs

This section covers the whole field of photomicrography as applied to materials, testing and research. While it is sponsored by ASTM Committee E-4 on Metallography, it includes such materials as textiles, paints, rubbers, etc., as well as metals. Student entries are invited.

Photomicrographs will be judged especially for their interpretive value.

Four categories have been established in this section on Photomicrography: (1) black and white; (2) color; (3) color transparencies; and (4) student. Each category will be displayed and judged separately.

While the general rules on Mounts and Identification and on Color Transparencies in the Photographic Exhibit apply to this section, more than one photomicrograph may be arranged artistically on the standard vertical 16- by 20-inch mount; however, it is suggested that all photomicrographs on a single mount be related in subject matter. Each mount should be accompanied by description (in duplicate, please, on letter size sheets) in 50 words or less of anything which might be instructive in either the method of preparation or the subject matter.

Electron micrographs

Entries are not limited to the field of metals, but may cover other materials, such as pigments, fibers, plastics, rubbers, cements, soaps, waxes, etc. The general rules on Mounts and Identification apply to this section on electron micrography. Either one or two electron micrographs may be arranged artistically on the standard 16- by 20-inch mount; two micrographs on a single mount should be related in subject matter. The accompanying description should contain not more than 50 words, and in addition to describing the subject matter of the electron micrograph, should also indicate the significance of the finding, or its contributions to the particular field of materials involved. The judging will be based primarily on the technical importance of the micrographs, and only to a lesser degree, on their photographic excellence. The title should contain the following information:

Original magnification, final magnification, and a brief reference to the method of sample preparation (that is, replica technique, ultra-microtome section, dispersion in plastic film, etc.).

Student Participation in the Photomicrographic and Electron Micrographic Exhibits

Student photomicrograph and electron micrograph entries should be submitted on standard 16- by 20-inch mounts either singly or as a related series, i.e. diffusion gradient studies, transformation structures in steel, etc. No printing or description should appear on the front of the mount but a description should be submitted in 50 words or less which description should be attached to the back of each mount, or shipped with the material carefully identified. This description should include information concerning the polishing technique used, the etching reagent employed, and the magnification and any pertinent optical data.

Desirable entries could include ferrous and nonferrous metals and alloys in cast or wrought form, light metals and alloys, structures obtained by various heat treatments and photomicrographs showing transitions or changes during processing. Such materials as textiles, rubbers, paints, etc., as well as metals are acceptable.

Student prizes will be awarded for exceptional work entered by undergraduates.

Interpreting Preliminary Measurements

By W. J. Youden[1]

IN A RECENT STUDY of the strength of the bond between steel beams and concrete there were three conditions of steel surface and three specimens for each condition. The investigator assumed that these nine results hardly justified statistical examination. Was this a valid assumption?

Many workers associate statistical techniques with extensive collections of data, yet do not hesitate to draw conclusions by visual examination of a few results. They may be unaware that statistical techniques are available for maximum efficiency in evaluating data regardless of the number of measurements available. If the results in hand constitute all the available information, the investigator cannot do a better job and may not do as good a job as the statistical formulas.

There is an important phrase in that last sentence. The phrase is "all the available information." Very often the investigator has much experience with exactly the type of measurement in question. This background of experience provides a reliable estimate of the magnitude of the experimental error in such work. Specifically, if the investigator has built up a firm estimate of the maximum difference that may occur between duplicate measurements, he can quickly pass judgment on two results when each result is on a different material. If the difference between the two results exceeds the maximum difference found between duplicate tests on the same material, he will believe the materials differ in the property measured. There is a slight vagueness in the term "maximum difference," but in practice the experienced worker develops good ability to evaluate data obtained in familiar situations.

When limited amounts of data have been obtained by an established testing procedure on material similar to those previously worked upon, the backlog of prior information greatly assists in the interpretation of the data. Indeed, confidence limits may be stated for a single result. Statistical formulas are completely useless when confronted with a single result. They are severely handicapped unless there are enough repeat results to permit an estimate of the experimental error. Something of the order of twenty pairs of duplicates, or ten sets of three repeat measurements, or seven sets of four repeat measurements are necessary to give the statistical formulas an even break in competition with someone who, by *long* experience, has developed a keen judgement. Of course, if access to earlier data is possible, the statistical formulas will excel the investigator.

The odds swing in favor of statistical reasoning when a very few results, obtained under unique conditions, constitute the sole available information. The incident mentioned in the first paragraph fits this category. The steel beams were large, taken off a job, and imbedded in approximately one-ton blocks of concrete. This was no "recommended procedure." Rather, it was a test procedure devised for the task at hand. For obvious reasons only a few tests could be run. There is nothing wrong with a few tests, especially if it takes a rather large difference to be of any engineering importance. Large quantities of data often result in revealing differences that are "statistically significant" but without any engineering significance.

The three sets of results corresponding to the three surface conditions were not submitted to statistical analysis. Yet the visual judgment is a form of appraisal that simply bypasses the appropriate statistical formulas. The statistical formulas, given equal information, are bound to provide a more dependable appraisal than visual inspection. Examples of statistical reasoning are given in the following paragraphs.

Suppose two tests have been run on the same material using a completely new test procedure. What is the chance that a third test will give a result intermediate between the two results already in hand? We do not need to know what the first two results are in order to answer this question. It does us no good even to see them. We have absolutely no way of judging whether these two results are closer together than usual or farther apart than usual, because we know nothing about the reproducibility of the new test. We do know that if the average difference between duplicates is ten units, differences in the range from one to thirty units are to be expected. With a thirtyfold situation facing one, and not knowing whether this particular difference is unusually small or unusually large, the information is indeed slight. Nevertheless, an answer can be given to the above question. Nothing is assumed other than the absence of any trend in the series of measurements. That is, we assume that the results are independent of the order in which the measurements are made. If this cannot be granted, all bets are off. If the order in which the measurements are made is immaterial, we may imagine that the third result is in hand. Write each of the three results on a slip of paper and shake the three slips in a hat. What is the chance that the third result drawn from the hat falls between the two already drawn? Enumeration shows that there are only six orders for the letters *l, m, s*. They are *lms, lsm, mls, msl, slm,* and *sml*. In two of these the middle result, *m*, is the last one out of the hat. The chance, therefore, that a third result lies between the first two results is just one third. Two times out of three the third result is either larger or smaller than both of the two results in hand.

Consider the related question: What is the chance that the first two results bracket the "correct" result? The chance is one half—better than before. It is necessary to be quite clear as to what is meant here by the "correct" result. If many repetitions of the measurement could be made, with no change in conditions, the average of these many repetitions converges on what we call the "correct" result. It is "correct" for this procedure, using the available apparatus, under the existing circumstances. If the apparatus has an error of calibration, if the procedure has a bias, and if the environment imposes some additional bias, then all these combine to produce a net systematic or constant error which will be present in all the results. The scatter among the results reflects only the random errors. It is unreasonable to expect the *average* of repeat measurements to report on anything more than the performance of the given pro-

(*Continued on p. 991*)

[1] National Bureau of Standards, Washington, D. C.

AMERICAN SOCIETY FOR TESTING AND MATERIALS

post conference tour

FEBRUARY 9 - 17, 1962

TO MEXICO CITY & ACAPULCO

It is our pleasure to announce that following A S T M Committee Week in Dallas during February we have planned a stimulating post conference tour to Mexico City and Acapulco. We hope that you can arrange your plans so as to join us.

T. A. Marshall, Jr.
Executive Secretary

$175 Per Person
Double

ITINERARY

Friday, February 9, 1962: Depart Dallas Airport on American Airlines Flight 783 at 12:50 p.m. arriving Mexico City at 5:40 p.m. Only thirty seven tourist seats available on first come first served basis. Remainder are first class seats at slightly higher fare. Meeting and limousine transfer in Mexico City to Hilton Continental Hotel. First evening cocktail reception. No meals except one lunch are included in Mexico City portion of program to leave you free to enjoy the many wonderful dining facilities there. Saturday: Morning orientation tour of Mexico City. Private limousines and bilingual guide-chauffers. Afternoon tour to University of Mexico City with guided lecture through school of Engineering, Art and Design. Sunday: Tour to Benito Juarez housing project, visit to floating gardens of Xochimilco, luncheon in Mexican home and an afternoon of pomp, ceremony and thrills at the Bull Fights. Monday and Tuesday free days for shopping and adventure of your own choosing.

Wednesday: Transfer to airport for one hour flight to Acapulco. Depart on flight Aeronaves 303 at 1:00 p.m. Air transportation to Acapulco included. Meeting and transfer to Las Brisas Hotel. Breakfasts and dinners included. Thursday: Free day for sunning or swimming from the beach or natural rock pool. Friday: Cruise during the afternoon on Acapulco Bay. Wonderful sights to see. Evening dinner at sophisticated La Perla and the night show of the famous cliff divers. Saturday: Frequent plane departures from Acapulco permit home transportation to be arranged to suit your convenience without lengthy lay-overs enroute to your home city.

Program includes hotel accommodations in Mexico City and Acapulco. No meals in Mexico City except as indicated. Transfers, hotel reception, sightseeing one way air to Acapulco. It does not include air Dallas to Mexico City which is $54.90 tourist, $69.80 first class. Air return from Acapulco to home city. $4.00 Mexican Tourist Visa or purchases of a personal nature. Proof of U.S. citizenship is required as well as valid smallpox vaccination for re-entry.

TO: Thomas A. Marshall, Jr.
Executive Secretary
A S T M
1916 Race Street
Philadelphia 3, Pa.

NAME: _____ Single: _____

ADDRESS: _____ Double: _____

_____

Enclosed is my deposit of $_____ ($25 per person) for _____ number of persons towards the A S T M Post Conference Tour to Mexico City and Acapulco. Balance to be paid on or before January 8th, 1962. I do ___do not___wish Embassy Tours to arrange air transportation Dallas/Mexico and return.

Please make all checks payable to American Society for Testing and Materials.

Society Affairs

Electroforming Symposium to be Highlight of Committee Week

MORE THAN 1200 of America's leading engineers and scientists are expected to meet in Dallas, Tex., during the annual ASTM Committee Week and Spring Meeting, February 5 to 9, 1962, at the Statler-Hilton and Sheraton-Dallas Hotels. Over 300 meetings will be held by some 45 technical committees whose task it is to keep ASTM standards up-to-date and to develop new ones as needed by industry.

A highlight of the week's activities will be the Symposium on Electroforming, including applications, uses, and properties of electroformed metals, to be held February 6 and 7, and sponsored by Committee B-8 on Electrodeposited Metallic Coatings and Related Finishes. This symposium, presented by recognized authorities in the field, will be the first comprehensive coverage of the fast-growing electroforming industry.

The two-day session will be of great interest to materials engineers and designers looking for a new means of filling the design-technology gap. Every aspect of electroforming—the science of creating or reproducing objects by electrodeposition—will be covered. Papers and discussions will explore such vital topics as modern electroforming solutions used, the techniques employed, and the practical application of electroforming in the manufacture of many essential products used in such diverse industries as the automotive, aerospace, and recording field. The complete program, including titles and authors of the twelve papers, appeared in the November issue of *MR&S*.

Other Events

Two other special events will be held during the week at which outstanding speakers will address the meeting. Dr. Marcus Long, professor of philosophy, University of Toronto (Canada), will speak on the subject "Are Engineers People?" at a dinner on February 6, sponsored by the ASTM Southwest District Council. The Society's Division of Materials Sciences will sponsor a luncheon on February 7 at which an address on "Ultrapure Materials" will be given by Dr. Alan Franklin, chief of Division of Mineral Products, National Bureau of Standards.

1962 Materials Testing Exhibits

1962 WILL SEE THE Society sponsoring two outstanding Materials Testing Exhibits. The first will be the biennial exhibit to be held during the 65th ASTM Annual Meeting at the Statler-Hilton Hotel, New York City, June 25–29. The second will be held in conjunction with the 4th Pacific Area National Meeting at the Statler-Hilton Hotel, Los Angeles, October 1–5.

Manufacturers and distributors of research, testing, and scientific apparatus and laboratory supplies; laboratory supply houses; and other firms associated with materials research and testing are being invited to take part in this outstanding educational feature of the Annual Meeting. For the first time independent testing laboratories will be invited to exhibit and describe their materials research and testing services.

Hundreds of items ranging from small hand-operated instruments and electronic control devices to giant electronically operated universal testing machines will be on display.

Several hundred apparatus manufacturers believed to be eligible to exhibit have been invited to apply for space. Those who have not received information may receive it by writing to: Fred F. Van Atta, exhibit manager, American Society for Testing and Materials, 1916 Race Street, Philadelphia 3, Pa.

Photographic Exhibit

Another educational feature of the Annual Meeting will be the Photographic Exhibit to be held in connection with the Materials Testing Exhibit. The Photographic Exhibit will feature electron micrographs ranging up to 50,000×, photomicrographs, photomacrographs, and general photographs illustrating research and testing procedures.

Full description and an application form for entries will be found on pages 983 through 986. Additional application forms may be had on request from ASTM headquarters.

Offers of Papers for 1962

THE ADMINISTRATIVE Committee on Papers and Publications will meet early in February to consider the papers to be published by the Society in 1962 and to develop the programs for the Annual Meeting (New York, June 24–29) and the Fourth Pacific Area National Meeting (Los Angeles, Sept. 30–Oct. 5).

All those who wish to offer papers for presentation at either or both of these meetings and publication by the Society should send these offers to Headquarters *not later than January 10, 1962*.

All offers should be accompanied by a summary that makes clear the intended scope of the paper and indicates features of the work that will, in the author's opinion, justify its publication and inclusion on the program.

Forms for supplying this information are available from ASTM Headquarters.

Papers Invited for Joint Navy–ASTM

Symposium on Standards for Filament-Wound Reinforced Plastics

ASTM WILL COOPERATE with the U. S. Navy in sponsoring a two-day Symposium on Standards for Filament-Wound Reinforced Plastics, June 6–7, 1962, at the Naval Ordnance Laboratory, Silver Spring, Md.

With the rapid recent developments in the techniques of winding high-strength glass and other fibers and bonding with resins to produce strong and lightweight structures has come a need to assess the quality of the structures nondestructively and to set quality of raw materials and techniques to assure product quality.

The four sessions will include papers on the research and development aspects both of the structures and of the component materials—resins, reinforcements, and finishes. Also to be included are papers on engineering evaluation of filament-wound structures for determining their performance under stress and in adverse environments—land, sea, air, and space—and for determining safe limits of stress and exposure. Finally, the symposium papers will cover inspection and nondestructive testing, including methods for detecting and classifying defects, and the establishment of philosophies for setting standards for acceptance or rejection.

The program has not yet been closed, and the symposium committee invites the submittal of additional papers for consideration. Titles and 200-word abstracts should be sent to H. A. Perry, Naval Ordnance Laboratory, Silver Spring, Md. Closing date for papers is January 15, 1962.

REPORT OF NOVEMBER MEETING:

Administrative Committee on Research

THE RESEARCH COMMITTEE is doing something about improving the dissemination of information. If a plan under discussion in the committee materializes, the Society will publish "Reviews of Reviews" in selected materials fields. The plan as presently outlined, which is subject to modification, will involve the selection of the areas to be covered in the reviews, establishment of a library search project to be supported by the Society, and the selection of experts in each of the materials fields to prepare critical reviews of the review articles and books in each field which appear annually. These reviews would be published by the Society, probably in *Materials Research & Standards*, though the means for publication have yet to be developed. The plan could go forward in three separate steps: (1) the collection and publication of annotated bibliographies of review articles and books, (2) the publication of critical reviews, and (3) the publication of state-of-the-art reports or monographs.

In developing plans for this project, the Research Committee is cognizant of the needs, especially in fields of technology, as contrasted with pure science, to bring to the attention of engineers and others concerned with the use of materials information being developed through research in a form that would be useful for application Members of the Research Committee feel that the Society can play a unique role in setting the pace for critical handling of the materials core of our technology.

The timetable for publication of the first reviews will depend on the speed with which the special committee set up to handle this project, under Erle Shobert II, can act, and also it assumes approval in general of the plan, both by the Society's Administrative Committee on Papers and Publications and the Board of Directors.

Long Range Planning

The Research Committee reviewed a rather extensive report and recommendations concerning research in the Society, prepared by the Long Range Planning Committee and approved by the Board for implementation by the Research Committee. The eight recommendations of the Long Range Planning Committee may be stated briefly as follows:

1. A definition of ASTM research necessary in stating the objectives of the Society's research is considered to include development of data on properties of materials, cooperative investigations to develop and improve test methods, surveys of the literature to provide background information on state-of-the-art, and cooperation with other organizations in the sponsorship and stimulation of research.
2. The Society should assemble and publish annually a complete listing of ASTM projects.
3. There should be published at least every two years a complete review of ASTM research projects.
4. The ACR should assist the committees of the Society in the planning and organization of research.
5. Where feasible, the Society should lend its prestige and encourage fundamental investigations in the sciences of materials.
6. The Society's research activities should be well publicized.
7. The staff assistance to the committee should be sufficient to carry forward its program.

These recommendations will continue on the agenda for future Research Committee meetings, with a view to making sure of their implementation. It was noted that most of the recommendations of the Long Range Planning Committee fall within the present activities of the Research Committee, and some are being carried forward by other committees. For example, Recommendation No. 4 concerning the planning of research programs is being carried forward in Committee E-11 on Quality Control of Materials in the development of a guide for interlaboratory evaluation of test methods and the design of experiments. The Research Committee has cooperated with Committee E-11 in the dissemination of its findings.

The committee recommended that additional staff effort be provided in keeping with Recommendation No. 7.

Numerical Data

Through its liaison member, Prof. W. L. Dolch, the Research Committee was a party to the recommendation to the Board to organize a Special Committee on Numerical Data, which was approved by the Board at its meeting in September. Professor Dolch will continue this liaison on the new committee. The scope of the new committee as approved by the Board is:

1. Encourage accumulation, evaluation, and dissemination of data on pure substances and commercially important materials.
2. Improve communications among ASTM groups and others.
3. Encourage use of standard methods for presentation of data.

The committee authorized an expenditure of $2500 from the Research Fund to support a study of the Termatrex inverted index system for retrieval of absorption spectral data. This project is under the auspices of ASTM Committee E-13 on Absorption Spectroscopy.

Interpreting Preliminary Measurements (ACR Notes)

(*Continued from p. 987*)

cedure with the particular equipment under the existing conditions.

Only one assumption need be made to demonstrate that the answer to the last question is one half. If the random errors are equally likely to be positive or negative, the chance of getting two measurements with deviations of different signs is just the same as getting both a head and a tail when two coins are tossed:

Nickel	H	H	T	T
Cent	H	T	H	T

or:

1st result	+	+	−	−
2nd result	+	−	+	−

There are only four possible outcomes, and for two of these the deviations have unlike signs. If one sign is positive and the other negative, the two results must bracket the "correct" value. Thus the chance is one half. It should be better than before. The "correct" average will not wander about as a single result will!

These examples illustrate the rigorous approach of statistical reasoning. One further example will be given. Suppose five repeat tests have been made on material A and four tests on material B. When the nine results are arranged in order of magnitude, largest to smallest, the following arrangement is obtained:

BBBAABAAA

The three largest results are from material B. It is also known that material B is material A which has been treated in an effort to *improve* the property which has just been tested. How convincing is the evidence that the treatment has improved the material? Again put nine slips of paper in a hat, four marked with B, the other five with A. What is the chance that the first three drawn will all be B's? It is $\frac{4}{9} \times \frac{3}{8} \times \frac{2}{7}$, or $\frac{1}{21}$. Thus it is a twenty-to-one shot against B showing the three best results if the treatment has not improved the material. Drawing from the hat gives each slip of paper equal opportunity to be drawn. Thus a quantitative statement of confidence can be made about these few results quite apart from any prior knowledge of the uniformity of the material or the errors in the test procedure.

Investigators will find simple statistical tests useful when the decision to continue or abandon a study must be made on the basis of a few preliminary measurements.

TECHNICAL COMMITTEE NOTES

Electrical Insulating Materials (D-9)

Following the Annual Meeting, the Society issued a new Tentative Specification for Copper-Clad Thermosetting Laminates for Printed Wiring (D 1867), based on a recommendation from Committee D-9. At its meeting in Montreal, October 16–18, Committee D-9 approved the addition of a new grade, FR-2, to this specification covering a paper base, phenolic resin, fire-resistant type of material. Three other fire-resistant materials are included in the specification covering epoxy-glass and paper-base material.

The committee has for some time been working with the Electronic Industries Assn. and the National Electrical Manufacturers Assn. on a research program at the University of Delaware to develop improved methods for testing insulation resistance, particularly for the metal-clad insulated materials used in printed wiring. The committee will cooperate in an extension of this program to investigate shear and punching properties of these materials.

Properties of insulating materials at microwave frequencies are being investigated by the committee. Interlaboratory tests on dielectric constant and dissipation factor of ceramic materials at microwave frequencies are in progress. Also under investigation are test methods for these properties at high temperatures and below 100 Mc.

Concrete Pipe (C-13)

The widely used specification for reinforced concrete pipe (C 76) was further improved as the result of action taken at the meeting of Committee C-13 held at the Union League Club, Chicago, Ill., October 11–13. Action was approved to further clarify the strength of welded splices in reinforcing cages to allow a core of less than 3½ in. in diameter when testing small diameter pipe, and to include the use of portland-pozzolan cement (Specification C 340). Further studies will be given to possible reduction in steel areas based on recent test data on strengths of laps and welds and to make classes II and III more nearly reflect the actual strength of pipe in the smaller diameters.

After careful study, action was taken to remove all descriptions of test methods from each of the specifications under the jurisdiction of Committee C-13. It is proposed to publish the methods of test as a separate standard.

The specification for rubber gaskets (C 443) was given a careful review with one action taken at this time, that is, to reduce the allowable angle of taper of joints from 12 to 10 deg.

A special luncheon was given in honor of R. R. Litehiser, retiring chairman, who has served in that capacity since 1953.

Plastics (D-20)

At a week-long series of meetings October 16–20, in Montreal, Committee D-20 gave final approval to the following items for action by the Society:

New Tentatives:

- Test for Ignition Properties of Plastics,
- Method for Preparation of Compression-Molded Polyethylene Test Samples,
- Specification for Poly(Vinyl Chloride-Vinyl Acetate) Compounds,
- Specification for Polyethylene Pipe,
- Recommended Practice for Extrusion Quality of ABS Pipe by Acid Immersion, and
- Specification for Glass Fiber Reinforced Polyester and Acrylic Corrugated Structural Plastics Panels.

The committee also recommended withdrawal of the Method for Modulus of Elasticity of Thin Plastic Sheeting (D 1530), since this determination is covered adequately elsewhere.

The committee also has a number of new items nearing completion:

- A Method for Tear Propagation Resistance of Plastic Films,
- A Method for Infrared Spectrophotometric Analysis of Components in Poly(Vinyl Chloride) Compounds,
- A Recommended Practice for Interlaboratory Testing of Plastics,
- A Recommended Practice for Oven Heat Stability of PVC Compounds,
- A Method for Softening of Organic Coatings by Plastics Compositions,
- A Method of Determining Dimensions of Plastics Pipe, and
- A Specification for Polyethylene Film and Sheeting.

Work continues on the development of methods for ablation resistance and nondestructive testing of reinforced plastics. Progress is being made toward a symposium on Standards for Filament-Wound Structures, to be sponsored jointly by the Society and the Navy Department and to be held in June, 1962, at the Naval Ordnance Laboratory in Silver Spring, Md. (see p. 990). Chairman of the Symposium Committee is H. A. Perry of NOL, who is also chairman of the Subcommittee on Reinforced Plastics of Committee D-20.

Rubber and Rubber-Like Materials (D-11)

COMMITTEE D-11 ON RUBBER and Rubber-Like Materials announces three new styrene-butadiene rubbers (SBR) recently brought on the market. Assignment of numbers 1512, 1818, and 1819 were made by Subcommittee XIII on Synthetic Elastomers, B. S. Garvey, chairman, in accordance with the Recommended Practice for Description of Styrene-Butadiene Rubbers (SBR) and Butadiene Rubbers (BR) (ASTM Designation: D 1419–61 T). A description of the new SBR rubbers is as follows:

Number assigned	1512	1818	1819
Date assigned	10/12/61	10/2/61	10/17/61
Requested by	Phillips Chemical Co.	Copolymer Rubber and Chemical Corp.	United Carbon Co., Inc.
Distinctive feature	29 per cent bound styrene	Oil 37.5 PHR HI-AR, AR oil Black 75 PHR ISAF	
Close previous number, if any	Philprene 6630	Carbomix 3765	1809
Type	1500	1800	1800
Nominal temperature, deg Fahr	41	43	43
Activator	...	FRA	FRA
Shortstop	ND	ND	ND
Antioxidant	NST	ST	ST
Catalyst	OHP	OHP	OHP
Emulsifier	FA	mixed	mixed
Nominal bound styrene, per cent	29	23.5	23.5
Nominal conversion, per cent	60	60	60
Nominal Mooney viscosity, ML 1 + 4 (212 F), polymer	52	...	...
Nominal Mooney viscosity, ML 1 + 4 (212 F), compound	73 max	60	60
Coagulation	GA	acid	acid
Carbon black:			
Type	....	ISAF	HAF
PHR	....	75	75
Oil:			
Type	....	HI-AR	AR
PHR	...	37.5	37.5
Finishing	special	normal	normal

NOTE.—Abbreviations and symbols are defined as follows: FRA = free radical type, that is, iron pyrophosphate, peroxamine sulfoxylate. Nd = nondiscoloring. NS = nonstaining. ST = staining. OHP = organic hydro peroxide. FA = fatty acid. GA = glue acid. ISAF = intermediate super abrasion furnace. HAF = high abrasion furnace. HI-AR = highly aromatic. AR = aromatic.

Electrical Insulating Liquids and Gases (D-27)

USERS OF NITROGEN gas as an electrical insulating medium in cables, transformers, and the like or as an inert gas to displace oxygen or air in electrical apparatus can soon reference a new ASTM specification for nitrogen gas. Developed by Committee D-27 after nearly two years of work, the specification covers three types of nitrogen gas from 99.8 to 99.998 per cent purity, the remainder being hydrogen, oxygen, and water vapor. Dew point requirements range from −67 F to −75 F, depending on type. Dew point is a sensitive measure of the quantity of water vapor present.

As is usual in the development of an ASTM standard, a new specification nearly always reveals a need for new test methods. The new nitrogen specification provides a reference to hydrogen determination at levels near 1 per cent (D 1196–53), but still needed are methods for oxygen from 0.002 to 0.2 per cent and for low concentrations of hydrogen down to 0.005 per cent. As for dew point, the committee is evaluating the method developed for gaseous fuels (D 1142) to determine whether it can be adapted for this determination. A committee survey showed that there are at least eight basically different dew point methods in use. All will be investigated before a preferred method is selected.

Water, because of its high dielectric constant and strong affinity for dissolving ionic or conducting solids, is an unwelcome constituent in any insulating material. In its efforts to keep water content as low as possible, the committee continues to refine its analytical techniques for water in askarels and in mineral oil insulation. Further revisions in the Karl Fischer method for water (D 1533) may therefore be expected.

Other projects of the committee discussed at its meeting at the Cavalier Hotel, Virginia Beach, Va., October 9–11, 1961, included methods for coefficient of thermal expansion of insulating liquids (for measurement of volume at different temperatures), for oxidation stability of cable and capacitor oils, for thermal stability of askarels, and for color of insulating liquids.

Materials for Electron Tubes and Semiconductor Devices (F-1)

AT ITS MEETING at Skytop, Pa., November 2–3, Committee F-1 completed the following actions for recommendation to the Society:

New Tentatives:

- Method for Measuring and Counting Particulate Contamination on Surfaces,
- Method for Hydrophobic Surface Films: The Water Break Test,
- Method for Hydrophobic Surface Films: The Atomizer Test,
- Recommended Practice for Conversion of Weights and Measures from British to Metric System,
- Recommended Practice for the Temperature Measurement of Thermionic Emitters, and
- Specification for High Conductivity Composite Aluminum-Steel-Copper for Electron Tubes.

Apart from its regular program of work, the committee is concerned about the need for standardization efforts in new areas, particularly that of microelectronics. Officers of the committee and subcommittee chairmen will make up a special committee to study the standardization problems in this area. With staff cooperation, they will first survey the work in other committees of the Society of interest in the field of microelectronics. Typical of the areas of interest are plastics for encapsulation, printed circuit materials, spot welding of fine lead wires, electroplating, thermal and radiation degradation of insulation, and performance of materials in a

composite device under use conditions including vacuum and space environment. The committee will be largely concerned not with the individual materials that go into microelectronic circuits but rather with the problems of processing, joining, and performance of the materials in the composite microelectronic circuits.

The committee is making plans for a Symposium on Cleaning and Materials Processing for Electronics and Space Apparatus, to be held at the Fourth Pacific Area National Meeting of the Society in Los Angeles, September 30–October 5, 1962. While invitations for papers have gone out, the proposed three-day program has not yet been filled. Those interested in submitting papers for the symposium are requested to send a 200-word abstract to D. E. Koontz, Bell Telephone Laboratories, Inc., Murray Hill, N. J.

The committee continues to grow, with this meeting showing a net gain of eleven members, bringing the total membership to 254, representing 101 member organizations.

ASTM MEETINGS

Date	Group	Place
	1962	
Jan. 14–17	Committee D-19 on Industrial Water	West Palm Beach, Fla. (Town House)
Jan. 16–17	Committee A-6 on Magnetic Properties	Philadelphia, Pa.
Jan. 18–19	Committee E-18 on Sensory Evaluation of Materials and Products	West Palm Beach, Fla. (Town House)
Jan. 21–24	Committee A-1 on Steel	Atlanta, Ga. (Atlanta Biltmore)
Jan. 21–24	Committee D-5 on Coal and Coke	Pittsburgh, Pa. (Webster Hall)
Jan. 21–26	Committee D-2 on Petroleum Products and Lubricants	St. Louis, Mo. (Chase-Park Plaza)
Jan. 22–23	Committee B-1 on Wires for Electrical Conductors	Philadelphia, Pa. (Society Headquarters)
Jan. 22–24	Committee B-5 on Copper and Copper Alloys, Cast and Wrought	Philadelphia, Pa (Sheraton)
Jan. 24–26	Committee D-7 on Wood	Madison, Wis. (Forest Products Laboratory)
Jan. 29–31	Committee D-1 on Paint, Varnish, Lacquer and Related Products	St. Louis, Mo. (Statler)
Jan. 30	Mississippi Valley District (Joint with Committee D-1)	St. Louis, Mo.
Feb. 5–6	Committee B-4 on Metallic Materials for Thermostats and for Electrical Resistance, Heating, and Contacts	Pittsburgh, Pa. (Penn-Sheraton)
Feb. 5–9	**Committee Week**	**Dallas, Tex. (Statler-Hilton and Sheraton-Dallas)**
Feb. 9	Washington District	Washington, D. C.
Feb. 15–16	Committee E-15 on Analysis and Testing of Industrial Chemicals	Philadelphia, Pa. (Benj. Franklin)
Feb. 26–March 1	Committee D-20 on Plastics	Pittsburgh, Pa. (Penn-Sheraton)
Feb. 27–March 2	Committee D-13 on Textile Materials	New York, N. Y. (Sheraton-Atlantic)
Feb. 28–March 2	Committee D-9 on Electrical Insulating Materials	Pittsburgh, Pa. (Penn-Sheraton)
Last week in Feb.	Committee A-3 on Cast Iron	Cleveland, Ohio
June 24–29	**Annual Meeting**	**New York, N. Y. (Statler)**
Sept. 30–Oct. 5	**Pacific Area Meeting**	**Los Angeles, Calif. (Statler-Hilton)**
	1963	
Feb. 4–8	**Committee Week**	**Montreal, P.Q. (Queen Elizabeth)**
June 23–28	**Annual Meeting**	**Atlantic City, N. J. (Chalfonte-Haddon Hall)**

Water Pollution Conference Set

THE FIRST INTERNATIONAL Conference on Water Pollution Research is to be held in London, September 3–7, 1962. This one-week conference will present 48 papers and prepared discussions on recent research advances in the areas of self purification of fresh water streams, the effects of pollution on fisheries, the treatment of sewage and industrial wastes, and the effects of pollution on the marine environment.

Participating in the program will be scientists and engineers from the United States, Great Britain, Europe, Soviet Russia, and Japan. This conference is sponsored in the United States by the Water Pollution Control Federation in cooperation with other technical societies.

Chartered airliners for American participants are now being scheduled and technical tours through Europe prior to the conference are planned.

Further information can be obtained from W. Wesley Eckenfelder, Jr., Manhattan College Environmental Engineering Research Laboratory, 514 Sylvan Ave., Englewood Cliffs, N. J.

Progress in International Plastics Standards

THE INTERNATIONAL Organization for Standardization's Technical Committee 61 on Plastics continued its outstanding record of progress in establishing agreements on test methods, terminology, and specifications for commercial plastics during its meeting in Turin, Italy, October 2–7. Four new test methods were approved for publication. In addition, four new drafts will soon go to the 45 ISO member nations for letter ballot, and five new proposals will be studied by the 35 TC 61 member countries. Robert Burns, of the National Academy of Sciences, was this year's meeting chairman.

At this meeting, the new cellular plastics working group, under the leadership of E. A. Hafner, Naugatuck Chemical Div., U. S. Rubber Co., reviewed over 30 national standards on rigid cellular plastics from member countries.

A recent move by both the European Economic Community and the European Free Trade Assn. to coordinate their standards activities with ISO/TC 61 makes it more apparent to American manufacturers that their participation in, and support of, the ISO plastics program will have important bearings on their trade with Western Europe. Soviet bloc nations likewise show increased intensity of interest in ISO plastics work.

U. S. A. National Committee Chair-

man A. C. Webber of DuPont reports that with this year's activity, the plastics industry can expect upwards of 40 internationally agreed-on methods to be available within the next year or two for coordination with the national standards work of the various member bodies. Availability of these methods means a marked speed-up in technological exchange and in the conduct of technical work across international borders.

Members of Iron and Steel Institute of Great Britain Guests of ASTM

A GROUP OF distinguished members of The Iron and Steel Institute of Great Britain and their wives were guests at a luncheon given in their honor by ASTM on November 6, at the Warwick Hotel in Philadelphia.

The group was welcomed to Philadelphia by ASTM President Miles N. Clair and other Society members. Dr. Clair said, "ASTM is pleased to have the opportunity to entertain members of The Iron and Steel Institute, not only because of the tradition of cooperative research between the United States and Great Britain, but by the common goals promoted by our two organizations."

The visitors are among a group of about 100 members of the Institute attending a series of meetings and touring some of the major steel producing centers in the United States and Canada.

Many leading Americans have contributed to and are members of the British Institute, whose world-wide membership is made up of individuals in the iron and steel industries for the purpose of discussing technical problems of common interest. Andrew Carnegie was president of the Institute from 1903 to 1905.

A meeting of the Institute has not been held in this country for 57 years. The first meeting held in the United States was 71 years ago when U. S. General William Tecumseh Sherman addressed the group at Delmonico's Restaurant in New York City.

MEMBERS OF BRITISH IRON AND STEEL INSTITUTE WITH DR. CLAIR

(Standing, left to right) Mr. R. W. Evans, T.D., honorary member of council; Dr. A. H. Leckie, Sir Robert Hadfield Medallist; Mr. E. W. Voice, assistant director, British Iron and Steel Research Assn.; and Dr. J. W. Jenkin, honorary vice-president. *(Seated, left to right)* Baron Walckenaer, Chev. de la Legion d'Honneur, honorary vice-president; Dr. Clair; and Sir Andrew McCance, F.R.S., past-president.

ACTIONS ON STANDARDS

The Administrative Committee on Standards is empowered to pass on proposed new tentatives and revisions of existing tentatives, tentative revisions of standards, and the withdrawal of tentatives and standards offered between Annual Meetings of the Society. On November 7, 1961, the Standards Committee took the following actions. Anyone interested in securing copies of the standards should write to Headquarters regarding their availability.

Copper

Standard Specification for Seamless Copper and Copper Alloy Rectangular Wave Guide Tube (B 372–61)

Tentative Revision.—Five additional sizes of rectangular wave guide tube have been added to Table III of the specification as a tentative revision.

Adhesives

Tentative Method of Test for Penetration of Adhesives (D 1916–61 T)

New Tentative.—This method determines the penetration under pressure of adhesives used in systems where at least one of the adherents is porous. It is particularly adaptable for use with starch or starch-based adhesives commonly used in the paper-converting industry. The method is useful in selecting adhesive systems for a particular application and in modifying adhesive systems to obtain maximum performance without excessive penetration of the adhesive into the substrate of the adherents.

Nondestructive Testing

Tentative Recommended Practice for Fabricating and Checking Aluminum Alloy Ultrasonic Standard Reference Blocks (E 127–58 T)

Revision.—Improvements have been made in the equipment calibration procedures for checking ultrasonic standard reference blocks, and several new sets consisting of numerous blocks have been added to the recommended practice.

HRB Launches Expansion Program

AN EXPANSION program for the Highway Research Board got under way in November with announcement of a new industrial associate category.

The Board, which is being called upon for more research correlation service to state highway departments, universities, and private industries involved in highway development and transportation, has been promised substantial assistance in such an expansion by the U. S. Bureau of Public Roads and the American Association of State Highway Officials.

It is expected that industries which depend heavily upon improvement of the nation's highway systems through research will also participate in the expansion program.

The Board's larger budget will permit enlargement of the professional engineering staff, a step-up in its publication program, and an expansion of the research correlation service.

Industry officials desiring more information about Board activities and the new associate membership should write to the Highway Research Board at 2101 Constitution Ave., N. W., Washington, D. C.

High-Speed Testing Explored

EQUIPMENT FOR testing materials at high speeds, and interpretation of results in terms of material behavior and properties were among the principal features of the Third Annual Symposium on High-Speed Testing held in Boston, Mass., October 26 and 27.

Equipment described ranged from flywheels through damped, pneumatically driven pistons, to equipment capable of heating metal accurately at rates of many thousands of degrees per second. Sensitive low-mass measuring devices have been developed for fast, accurate recording of tests carried out in extremely short times. From high-velocity straining and subsequent relaxation have come new insights into viscoelastic behavior of materials and the attendant structure of matter.

The symposium was organized by Plas-Tech Equipment Corp., of Natick, Mass. Co-chairmen were Prof. F. R. Eirich, Polytechnic Institute of Brooklyn, and ASTM National Director A. G. H. Dietz, M.I.T. The following papers were presented:

A Flywheel Impact Tester for Measuring Physical Properties of Tire Cords—C. S. Kemic and J. P. Parker, American Enka Corp.

Basic Design Features for a Pneumatically Driven, Hydraulically Damped, High-Speed Tester—R. D. Spangler, E. I. du Pont de Nemours & Co., Inc.

The Viscoelastic Behavior of Isotactic Polypropylene Fibers—R. C. Laible, U. S. Army Quartermaster R & E Command, and H. M. Morgan, Fabric Research Laboratories, Inc.

Progress Report, Task Group on High-Speed Testing, ASTM Committee D-20 on Plastics—G. D. Patterson, Jr., E. I. du Pont de Nemours & Co., Inc., and W. R. Smith, U. S. Rubber Co.

Stress-Strain Testing of Rubbers at High Rates of Elongation—M. L. Dannis, B. F. Goodrich Co.

A Modified Method of Reduced Variables for Stress Relaxation—F. S. C. Chang, Borg-Warner Corp.

Apparatus for Studying the Effects of Rapid Thermal Cycles and High Strain Rates on the Elevated Temperature Behavior of Metals—W. F. Savage and E. J. Nippes, Rensselaer Polytechnic Inst.

Viscoelastic Characterization of Solid Propellants by Transient Test Techniques—J. W. Jones, Grand Central Rocket Co.

Characterizing Impact Behavior of Thermoplastics—W. E. Wolstenholme, U. S. Rubber Co.

Behavior of High-Strength Parachute Components at Impact Velocities up to 800 Feet Per Second—H. M. Morgan, R. J. Coskren, and C. C. Chu, Fabric Research Laboratories, Inc.

TECHNICAL COMMITTEE OFFICERS

OFFICERS OF COMMITTEE D-26 ON HALOGENATED ORGANIC SOLVENTS

Left to right: G. M. Ford, vice-chairman, The Bendix Corp.; Mrs. Wanda L. Campbell, secretary, Vego Chemical Corp.; W. D. McMaster, chairman, General Motors Corp.

OFFICERS OF COMMITTEE E-10 ON RADIOISOTOPES AND RADIATION EFFECTS

Left to right: O. Ken Neville, secretary, Nuclear-Chicago Corp.; E. B. Ashcraft, chairman, Westinghouse Research Laboratories; G. W. Pomeroy, vice-chairman, General Electric Co., Aircraft Nuclear Propulsion Dept.

OFFICERS OF COMMITTEE C-18 ON NATURAL BUILDING STONES

Left to right: F. L. Knoblock, liaison officer, consulting member of Committee C-18; F. S. Eaton, Chairman, Research and Design Inst., Inc.; W. F. Mullen, secretary, Pennsylvania Slate Producers Guild, Inc.; A. Hockman, vice-chairman, National Bureau of Standards. At rear is ASTM test wall of national building stones.

MATERIALS SCIENCES

Research and Graduate Study

THERE IS A ferment in universities nowadays about how to organize for instruction and research in the materials sciences. Since this subject is interdisciplinary, it means a departure from the old disciplinary compartments that exist in educational curriculums. How one university is meeting this challenge was reported by Maurice E. Bell[1] in an article, "Materials Science—A Plan for Research and Graduate Study," which appeared in *Mineral Industries*, a monthly publication of The Pennsylvania State University.

Professor Bell examines what is taking place in the major universities and institutes of technology and outlines a plan which is being instituted at Penn State for research and graduate instruction in the materials sciences. There is a question how far the emphasis on "materials science" should go and, in particular, whether it should be allowed to revolutionize undergraduate programs in metallurgy and metallurgical engineering by making them broad and general at the expense of training in depth.

The need for a program in the materials science area has been met at Penn State in a different way. For the present, the undergraduate curriculums and graduate programs in metallurgy, ceramic techology, engineering mechanics, and other aspects of materials have been retained, but a new interdisciplinary graduate major has been instituted in solid-state technology. This action provides for interdisciplinary graduate instruction and research without disturbing the training of engineers and technologists for a bachelor's degree in the established fields of metallurgy and ceramics. In giving the background for this decision, Dr. Bell discusses the development of the idea of materials science over the past ten years, observes the growing tendency for universities to establish both bachelor and graduate degree courses in materials science, and notes the growing role of the Federal government in major support of materials science centers in the universities.

Dr. Bell also notes the problems facing the professional societies, pointing out, for example, that no less than 15 societies and organizations held national meetings on some aspect of semiconductor materials within a single year.

The Penn State Plan for Materials Research

The Penn State plan for meeting the materials science challenge is outlined by Dr. Bell as follows:

"A plan has been evolving at the College of Mineral Industries for the past three or four years which it is hoped will result in an activity in materials research that is above the critical size for productivity, will provide the necessary facilities for work on materials whose character we can control ourselves, and will be in support of the interdisciplinary graduate major in Solid State Technology.

"In brief, this plan is based upon the extensive and productive research in phase equilibria, solid state reactions, and synthesis which has been developing in this College during more than 10 years. It is proposed to add a facility for research in methods of crystal growing and purification and for limited-scale production of single-crystal or ceramic samples for research; a measurement facility; additional techniques for characterization (measuring the crystalline perfection); and etching and surface treatment facilities. Figure 1 gives in schematic form the plan for materials research.

"While it is at first intended to do research principally on oxide materials and semi-insulators, which is a logical continuation of work carried on here over the past dozen years, it should be noted that the plan is equally applicable to physical metallurgy and even to research on plastics, organic semiconductors, or glasses. The salient features are that the work is organized so that samples of controlled quality may be obtained in appropriate form for research, whether in single crystals, in high polymers, in glasses, or in ceramic bodies. Provision is also made for feeding back the observations and interpretations from the later stages of the research to the synthesis and fabrication stages, with the ultimate aim to learn how to tailor the material to the application.

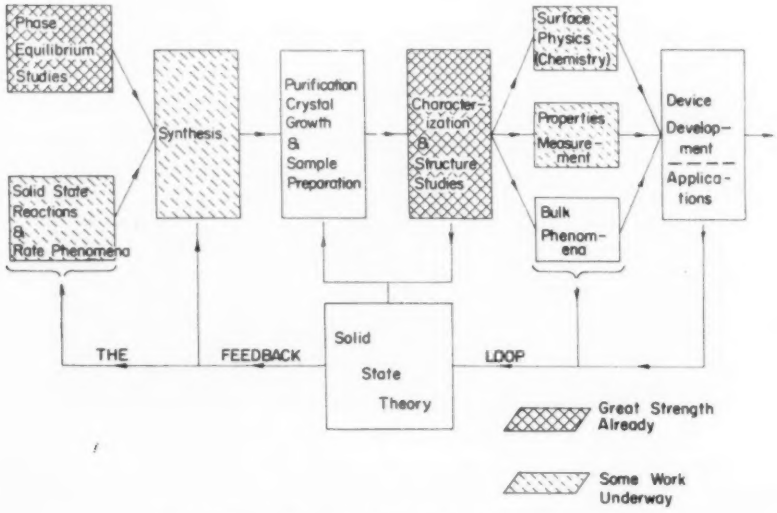

Fig. 1.—Block diagram of a plan for materials research.

Semiconductors: An Example

"One significant area of modern materials research concerns the effect of dislocations, impurity content, other kinds of defects, and previous thermal history upon the electrical behavior of a semiconductor when fabricated into an electronic device called a transistor. In order to do research which is competitive with the major industrial laboratories in this field, the university professor must have at his command, or at least be part of, a group which can provide samples with the proper composition of the material to be studied; [the group] must be able to produce single crystals, large enough, and with controlled impurities (doping), dislocations, and other defects; there must be available a crystal structure laboratory to characterize the material; and neither last nor least a laboratory and skilled investigators must be available where sophisticated measurements such as Hall mobility, conductivity by the four-point probe method, and minority carrier lifetime measurements can be made and interpreted routinely. It would be handy also to have a "tame" theoretical physicist around to indicate which experiments are likely to be more profitable at a given time and to help interpret the results.

"This example was given to show that the life of an individual investigator in materials research is likely to be hard, and particularly so if he chooses to carry on his researches in the main stream.

Progress to Date

"Some of the plan diagrammed in Figure 1 has already been realized in the College of Mineral Industries. In addi-

[1] Professor of Geophysics, Assistant Dean for Research, and Director of the Mineral Industries Experiment Station, The Pennsylvania State University.

tion to the existing work on phase equilibria, a new laboratory has been assembled, assisted by a grant from the U. S. Atomic Energy Commission for physical property measurements on materials. Measurements can now be made of resistivity, dielectric constant and dielectric loss, and magnetic susceptibility and loss, all over a range of temperature, pressure, and frequency. Thermal expansion coefficients and crystal perfection can be measured by X-ray methods. Equipment and techniques will be added soon to measure thermal conductivity of materials in small samples, thermoelectric power, and elastic properties and internal friction.

"The College of Mineral Industries is especially well situated in the area of characterization. This is because of the long tradition of research in the natural rocks and minerals and because the same skills and equipment are required to characterize materials, particularly inorganic materials, as are needed to understand the constitution of the rocks and minerals. Not least important is the experience which has been built up in the College in working out a scheme whereby expensive equipment like the electron microscope can be made available under the supervision of a specialist, to any research worker who desires to use these techniques in his research. Financing of these facilities, which are called the Mineral Constitution Laboratories, is accomplished under a system of established rates so that each investigator, through his own research budgets, contributes to the support of the technicians and equipment in proportion as he uses them. This arrangement, which could equally well be called the 'Materials Characterization Laboratories,' includes wet chemical analysis, optical, infrared, and ultraviolet spectroscopic analysis, fluorescent X-ray spectroscopy and X-ray powder analysis, X-ray single crystal cameras, electron microscopy and diffraction, and mass spectrometry. An electron probe microanalyzer will be added about January, 1962. Every effort is being made to keep all techniques up-to-date and to obtain new analytical and characterization techniques as they become available. A team of specialists supervises faculty members and students in use of the equipment and conducts research on the techniques themselves and on their application to minerals and materials."

Building Blocks for Concrete Research

THE SECOND CONFERENCE on Fundamental Research in Plain Concrete was held at the University of Illinois from September 5–8, 1961. It brought together more than 100 persons active in all phases of concrete research for a broad and informal exchange of ideas in this field.

The conference was guided in its planning and presentation by the Steering Committee of which Clyde E. Kesler and John W. Murdock of the University of Illinois served as chairman and secretary, respectively. The other members, representatives of the sponsoring organizations, were Leo H. Corning, Structural Div., American Society of Civil Engineers; Bryant Mather, American Concrete Inst.; Gene M. Nordby, Reinforced Concrete Research Council; Hubert Woods, Portland Cement Assn.; and Kenneth B. Woods, ASTM. The National Science Foundation supported the conference.

No formal proceedings of the conference were recorded. The informal discussions encouraged speculation on possible approaches to research even though it finally might prove fruitless. Most significant was the increased awareness of each participant of the many and varied tools that are being used to solve problems of concrete research. Each participant keenly perceived the gap in communications between the scientist and the engineer; recognition of this understandable but unnecessary gap might prove to be the first step toward closing it—something upon which efficient and more rapid progress depends.

Bryant Mather, a member of the Conference Steering Committee and an active ASTM member, summarized the conference succinctly in the following:

"The pervading theme of the conference appeared to be that progress to date in understanding the fundamental aspects of the behavior of plain concrete was being made at an accelerating rate but that, while the amount of knowledge available was doubling at smaller and smaller time intervals, the area of ignorance that was recognized was enlarging with equal velocity. It was agreed that we as yet had no satisfactory theory of strength or fracture, that recent work on kinetics of hydration had served primarily to disprove both previously held hypotheses, that work on flow behavior was as yet rudimentary, and that we were discovering previously unknown kinds of aggregate reactions at an increasing rate. It appeared to us that the breakthrough that was most needed in order to penetrate the barriers to understanding that were confronted in all the areas discussed was a knowledge of the nature, origin, and strength of the bonds that exist in concrete and serve to hold it together. This need was made explicit in the discussion of strength—which is essentially how do the bonds get as strong as they get, and in the discussion of fracture—which is essentially how does energy concentrate where it does and in amounts adequate to break bonds. The discussion of kinetics of hydration could be viewed as a discussion of how the bonds form, that on rheology as how the development of bonds affects flow behavior, and that on aggregate reactions as how the presence of aggregate brings about modification of the bond-forming and bond-breaking behavior of the system, concrete."

COMING MR&S PAPERS

Corrosion of Stainless Steel in the Presence of Concentrated Nitric Acid—Ch. Apert and Mme. Vialatte, Centre d'Essais des Propulseurs.

Dielectric Strength and Dielectric Breakdown Volume of Miniature Specimens—A. R. Blanck and B. T. Holman, Ordnance Corps, Picatinny Arsenal.

The Scientific Application of Particle Accelerators to Nondestructive Testing—E. A. Burrill, High Voltage Engineering Corp.

The Theta Specimen for the Determination of Tensile Strength of Brittle Materials—A. J. Durelli, Catholic University of America, S. Morse and V. Parks, Illinois Institute of Technology.

Apparatus for Obtaining Mechanical Properties at High Temperatures—D. H. Fisher, R. L. Carlson, and F. C. Holden, Battelle Memorial Inst.

Variations in Tensile Strength of Sintered Iron Powder Parts as a Result of Variations Between Different Furnaces and Sintering Practices—Ernst Geijer, Hoeganaes Sponge Corp.

Determining the Weight and Analysis of Unalloyed and Alloyed Coating Layers on Hot-Dipped Aluminum Coated Steel—L. C. Ikenberry, Armco Steel Corp.

Comparison of Visual and Instrumental Measurements of Specular Gloss of Glazed Ceramic Tile—A. M. Illing, Cambridge Tile Manufacturing Co.

The Bend Test Properties of 43XX-Vanadium Modified and 5 per cent Chromium Sheet Steels—E. P. Klier, G. Boras, and Jane Jellison, Catholic University.

Reflective Behavior of Transparent Plastic Films—R. R. Knittel, Union Carbide Co.

A Penetrometer Study of the In Situ Strength of Clays—R. L. Kondner, Northwestern University.

A Specimen for Use in Investigating the Stress Corrosion Cracking of Metals at Elevated Temperatures—H. L. Logan, National Bureau of Standards.

Improved Adiabatic Calorimeter for Concrete—David Pirtz, University of California.

A Statistical Comparison of the Wearing Characteristics of Two Types of Dollar Notes—E. B. Randall and John Mandel, National Bureau of Standards.

Comparison of Micro and Standard Tests for International Rubber Hardness—R. D. Stiehler and F. L. Roth, National Bureau of Standards.

A Model of the Mechanical Properties of Metals—F. B. Stulen, Curtiss-Wright Corp.

Glue? for Concrete Repair?—C. M. Wakeman, Port of Los Angeles.

NEW ASTM PUBLICATIONS

1961 Book of ASTM Standards: Six Parts Now Available

As is indicated by the dark-shaded books in the above photograph, six of the eleven parts of the 1961 Book of ASTM Standards (Parts 1, 4, 6, 7, 10, and 11) are now available. Thus more than half of this encyclopedic reference work on materials is now finding its way to the bookshelves of those who are responsible for the nation's materials technology and commerce.

In the following list of titles of the eleven parts, those now available are shown in boldface type. In some cases, number of pages and of standards are approximate.

Part 1—Ferrous Metals Specifications (1652 pages, 304 standards), list price $23, to members $18.50[a]

Part 2—Nonferrous Metals Specifications, Electronic Materials (1574 pages, 292 standards)

Part 3—Methods of Test for Metals (Except Chemical Analysis) (1186 pages, 151 standards)

Part 4—Cement, Lime, Gypsum, Mortar, Concrete, Mineral Aggregates, Bituminous Materials, Soils (1717 pages, 391 standards), list price $21, to members $17[a]

Part 5—Masonry Products, Ceramics, Thermal Insulation, Acoustical Materials, Sandwich and Building Constructions, Fire Tests (1352 pages, 304 standards)

Part 6—Paper, Packaging, Flexible Barrier Materials, Adhesives, Wood, Cellulose, Casein, Leather (1448 pages, 286 standards), list price $17, to members $13.50[a]

Part 7—Petroleum Products and Lubricants (1658 pages, 220 standards), list price $23, to members $18.50[a]

Part 8—Paint, Naval Stores, Coal and Coke, Gaseous Fuels, Industrial Aromatic Hydrocarbons, Engine Antifreezes, Industrial Chemicals (1911 pages, 410 standards)

Part 9—Plastics, Carbon Black (1096 pages, 211 standards)

Part 10—Textiles, Soap, Sorptive Mineral Materials, Halogenated Organic Solvents, Industrial Water, Atmospheric Analysis, Wax Polishes (1916 pages, 309 standards), list price $23, to members $18.50[a]

Part 11—Rubber, Electrical Insulation (1868 pages, 282 standards), list price $21, to members $17[a]

[a] Price for part in addition to the part received by member through membership privilege.

Materials and Electron Device Processing

STP 300, 292 pages, hard cover, price $8.00, to members $6.40.

The problems of reliability of complex electronic devices and of expensive space gadgetry have focused attention during recent years on the great importance that very small amounts of contamination can have in the functioning of these devices. Elaborate efforts go into control of minute amounts of contamination in the processing and fabrication of electronic components such as electron tubes and transistors, as well as fine machinery, drugs, and fuel and guidance systems for space vehicles.

Some solutions to the problems of contamination control and some approaches to solution of these problems in the electronics industry particularly, are covered in this volume containing papers presented at the second symposium on this general subject sponsored by Subcommittee X on Control of Contaminants of ASTM Committee F-1 on Materials for Electron Tubes and Semiconductor Devices. The first symposium, held in 1958, on Cleaning of Electronic Device Components and Materials, was published by the Society as *STP 246*.

Contents of this present publication are as follows:

The Role of Impurities in Impurity-Dominated Electronic Materials and Devices—F. J. Biondi.

Air-Borne Contaminants

Particulate Concentrations in Ultraclean Rooms—F. W. Van Luik, Jr.

A Comparison of Electrostatic and High-Efficiency Impingement Air Filters for Use in Device Development Laboratories—George Helmke.

Dust Monitoring by the Dry Slide Settling Technique—W. J. Whitfield, R. C. Marsh, and I. M. Kodel.

An Approach to Control of Transistor Processing Environments—C. A. Smith and T. Manns.

Size Distribution and Identification of Air-Borne Particulates—Fred Allison.

Analytical Methods and Instrumentation

Electron Beam Microanalyzer: A New Tool for Electron Device Development—J. S. Hayes.

Detection of Inorganic Contamination on Surfaces by an EMF Measurement—D. G. Schimmel.

Electrode Potential: A Tool for the Control Of Materials and Processes in Electron Device Fabrication. Part I: EMF-Time Studies of Clean and Contaminated Platinum Electrodes—D. O. Feder and E. S. Jacob.

Electrode Potential: A Tool for the Control of Materials and Processes in Electron

Device Fabrication. Part II: EMF Studies of the Behavior of 36 per cent Nickel-Iron Alloy in Hydrogen Perozide–Formic Acid Etchants—D. O. Feder, W. E. Howden, D. R. Huff, and J. W. Richards.

Use of Radioisotope Tracer Techniques in Contamination Studies—T. J. Bulat.

Gas-Phase Proportional Counting: A Radiotracer Technique for Examination Of Electronic Components and Materials—Herman A. Stern.

PROCESSING APPARATUS AND TECHNIQUES

Fluorine Release from Glasses—Josef Francel.

Elimination of Contaminants from Electron Tube Components: Automation of Chemical Processing—C. O. Thomas, W. H. Craft, and D. E. Koontz.

Transducer Parameters Affecting Sonic Cleaning—L. J. Lyons.

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Arc Sealing of Borosilicate Glasses—Morris Liebson.

MATERIALS AND PROCESSING TECHNIQUES

Recommended Practices for Safe Handling of Beryllium Oxide Ceramics—Laurence E. Ferreira.

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Comparison of Standard Leak Rates Measured by Viscous and Molecular Flow Techniques—D. W. Maurer.

Gas Composition During Pumping and in Sealed-off Power Tubes—P. F. Váradi, H. A. Langer, and M. N. Saltzman.

Determination of Trace Amounts of Oxygen in Protective Gaseous Ambients—D. O. Feder and W. H. Craft.

Mass Spectrometric Studies of Power Klystron Exhaust Processing—Lowell Noble and Robert K. Waits.

Quality Control of Getters—P. della Porta and E. Airoldi.

Residual Gas Content as a Function of Tube Processing—H. B. Frost.

INFLUENCE OF CLEANING ON DEVICE PERFORMANCE

Changes in Stability of Germanium Alloy Transistors Through Etching, Washing, and Encapsulation Processing—Arnold J. Borofsky.

Effects of Various Cleaning Methods on Electronic Components in the Micromodule—J. L. Vossen.

Noise-Tested Cathode Activation—F. Dlouhy and H. J. Schuetze.

APPENDIX

Organization of Committee F-1 on Materials for Electron Tubes and Semiconductor Devices.

Major Effects of Minor Constituents on the Properties of Materials

STP 304, 100 pages, hard cover, price $3.75, to members $3.00.

THE PURPOSE of the Division of Materials Sciences as stated in its scope includes "the promotion of knowledge of the nature of materials .... the Division will be concerned broadly with the relation of properties [of materials] to their structure and will give special attention to matters common to more than one material or class of materials."

The recent notable developments in solid-state electronics have emphasized the role played by extremely small quantities of "extraneous" materials in high-purity materials. That these effects have importance in other fields is recognized and was a main purpose of this symposium sponsored by the Division of Materials Sciences. The symposium treats the subject broadly, bringing together the points of view of a physicist, a chemist, a ceramist, and a metallurgist, considering impurity effects in crystalline solids, in liquids, and in ionized gases. The symposium thus reviews and provides common ground for understanding of effects of minor constituents in these different states of matter.

This symposium publication is the second in the Materials Science series sponsored by the Division of Materials Sciences. The first in the series, entitled "Properties of Crystalline Solids" (*STP 283*), comprises two symposia held in 1960, covering the topics "Recent Progress in Materials Sciences" and "Nature and Origin of Strength of Materials."

The contents are as follows:

Impurity Effects in High Purity Metals—G. A. Moore and L. L. Wyman, National Bureau of Standards.

The Effect of Impurities on the Properties of Ceramic Materials—Ivan B. Cutler, University of Utah.

Major Effects from Minor Constituents—Role in Organic Structural Polymers—J. F. Lontz, E. I. du Pont de Nemours & Company, Inc.

The Problem of Gas Purity in Plasma Physics and Technology—S. J. Buchsbaum, Bell Telephone Laboratories, Inc. and G. A. Sawyer, Los Alamos Scientific Laboratory.

Effects of Small Amounts of Extraneous Materials on Properties of Petroleum, Petroleum Products, and Related Liquids—Harold M. Smith, U. S. Bureau of Mines.

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Bibliography and Abstracts on Thermostat Metals (1806–1959)

STP 288, 68 pages, heavy paper cover, price $4.00, to members $3.20.

THIS BIBLIOGRAPHY brings together 519 references to the literature on thermostat metals covering the period 1806 to 1959. It is based largely upon a bibliography published by The American Society of Mechanical Engineers containing 320 references and covering the period up to 1947. Both the ASME and the Engineering Index kindly permitted use of their abstracts in the publication of this bibliography. Many of the supplementary items covering the period 1948 to 1959 were taken directly from Engineering Index and are so identified in the publication. The subject index includes the following general categories:

Applications—Chronometer
Applications—General and Miscellaneous
Applications—Instruments
Applications—Motor Protection
Applications—Temperature Regulation, General
Catalogs
Electric Current Effect
Forms—General and Miscellaneous
High-Temperature Performance
Historical
Iron-Nickel and Related Alloys
Manufacturing and Fabrication
Mathematical Treatment
Standards
Stress Analysis
Thermal Expansion

Five-Year Index

Index to ASTM Technical Papers, 1956–1960, 128 pages, cloth binding, price $3.50, to members $2.80.

THIS FIVE-YEAR index provides a detailed author and subject index to the technical papers and reports dealing with materials, particularly their properties and testing, appearing in ASTM publications from 1956 through 1960. It supplements the fifty-year index (1898–1950) and the five year index (1951–1955).

The index is a guide to any ASTM paper, whether published in the *Proceedings*, the ASTM BULLETIN, in a Special Technical Publication, or in a special compilation of standards. In addition, a number of technical reports have been referenced which, while not credited to a specific author, are felt to provide worthwhile information. A complete list of Special Technical Publications by serial number is included as part of the Index.

Errata: Textile Compilation

IN THE FIRST copies of the 1961 compilation of "ASTM Standards on Textile Materials" that were distributed, page 272 is incorrect. Page 272 should be the last page of Methods D 579 instead of a page from Methods C 110 as it appears in these copies of the compilation. A copy of the correct page will be furnished on request.

Steel Piping Materials

ASTM Specifications for Steel Piping Materials (18th Edition, 1961) 520 pages, hard cover, price $7.00, to members $5.60.

THIS NEW BOOK succeeds the 17th edition, of September, 1960. Of the 76 standards included, 55 are revisions and there are four new items that were not in the previous edition. Among the new items are two specifications for austenitic centrifugally cast steel pipe, including the product that is cold formed after being cast. Also a new specification for high-strength bolting materials covers commercial alloys A-286, 19-9 DL, Discaloy, and W-545. The fourth new standard includes general requirements for carbon, ferritic alloy, and austenitic alloy steel tubes. These are general requirements, common to some 17 specifications for steel tubes, which can be referenced in the individual product specifications.

The specifications in this compilation cover (1) pipe used to convey liquids, vapors, and gases at normal, elevated, and subatmospheric temperatures; (2) steel tubes for refinery service; (3) heat exchanger and condenser tubes; and (4) boiler and superheater tubes. To make the volume more complete there are included also specifications for castings, forgings, bolts, and nuts used in pipe and related installations.

Many of the specifications in this compilation are incorporated in the ASME Boiler and Pressure Vessel Construction Code. The American Standard for Wrought Steel and Wrought Iron Pipe (ASA No.: B36.10-1959) and the American Standard for Stainless Steel Pipe (ASA No.: B36.19-1957) are reprinted in this volume through the courtesy of The American Society of Mechanical Engineers.

This compilation, first published in this form in 1942, is an enlargement of a volume issued in previous years which was developed in cooperation with the Prime Movers Committee of the Edison El[illegible] Inst.

President Clair Speaks at Masonry Association Meeting

ON OCTOBER 12, ASTM President Miles N. Clair was luncheon speaker at the Eastern Area Meeting of the National Concrete Masonry Assn. at the Sheraton Hotel in Philadelphia. To the several hundred members present he described the history of the Society and how its work relates to the work of the Association. He also offered some advice in regard to procedures for improving the quality and acceptance of concrete masonry products and pointed out some of the trends in new equipment and types of products.

On October 18 and 19, Dr. Clair attended the meetings held in celebration of the 125th anniversary of the establishment of the United States Patent Office. At the anniversary dinner, which was attended by patent officials from this and many other countries, Dr. Clair was recognized as a member of the National Sponsoring Committee and as ASTM president.

Creep and Fracture Conference Now Creep Conference

THE TITLE OF the forthcoming Joint International Conference on Creep and Fracture has been changed to "Joint International Conference on Creep." This move was made to remove any implication that the conference would be concerned with low-temperature brittle fracture problems. The duration of the conference, originally scheduled for Aug. 25–28, 1963, in New York, has been changed to Aug. 25–29.

Chairman of the conference is M. J. Manjoine, Westinghouse Astronuclear Laboratories, Pittsburgh, Pa. Deputy chairman is J. J. Kanter, Crane Co., Chicago, Ill. Secretary is N. L. Mochel, Westinghouse Electric Corp., Philadelphia.

Papers are invited in the areas of fundamentals of creep, design techniques involving creep, and service experience with creep failure. Offers of papers should be sent to Mr. Mochel.

Antismog Measure in L. A. Takes Effect in 1962

THE LOS ANGELES Air Pollution Control District has announced the deadline to cease marketing gasoline having a Bromine Number of more than 20 as of June 30, 1962. An earlier announcement by ACPD inadvertently gave the deadline as Dec. 31, 1961. Step one of Rule 63 for reducing Bromine Number to 30 took effect on June 30, 1960. The Bromine Number, which is determined by ASTM Method D 1158, is a measure of the olefinic unsaturation in gasoline.

DISTRICT ACTIVITIES

CHICAGO

Speakers' Bureau Announced

THE CHICAGO DISTRICT has established a Speakers' Bureau consisting of some 60 speakers prepared to speak on 20 technical subjects ranging from air pollution to the treatment of wood. The 12-page roster of speakers lists engineers and scientists who have agreed to present discussions of their own specialities as used in industry.

The primary purpose of the program is to acquaint science and engineering students with the wide variety of uses to which their education can be directed.

Copies of the roster have been distributed to the members of the Chicago District and to the chairmen of all the other ASTM districts. The administrative Committee on District Activities has commended the example of the Chicago District to the other districts.

As the program operates in Chicago, when a request from a school is received for a speaker, arrangements are made to have a member of the Chicago District Council present to introduce the speaker and also to give a brief outline of ASTM activities. To date, 18 talks have been given this year.

The Chicago District Council is quite willing to help other districts establish similar programs by sharing their experiences in initating the program, financing and publicity problems and pitfalls that can arise. For this information, write to Chicago District Chairman, Mr. C. S. Macnair, Acme Steel Co., 135th Street and Perry Ave., Chicago 27, Ill. or the directors of the program, Dr. J. O. Osterberg, Technological Institute, Northwestern University, Evanston, Ill., or Dr. David N. Rickles, Chicago Board of Education, Fourth Floor, 3100 So. Kedzie Ave., Chicago 23, Ill.

PHILADELPHIA

THE HISTORY OF the development of ASTM, from its beginnings more than 60 years ago to the present, was explored by President Miles N. Clair in an address on October 30 at a meeting of the Philadelphia District on the campus of Swarthmore College, Swarthmore, Pa. Earlier in the day, the District Council sponsored a tour of the engineering facilities of Swarthmore College and a dinner in Beardsley Hall. Greeting the guests from the head table, in addition to Dr. Clair, were Samuel T. Carpenter, chairman, Division of Engineering, Swarthmore College; ASTM Executive Secretary Thomas A. Marshall, Jr.; and Herbert W. Stuart, chairman of the Philadelphia District Council.

Before his talk, Dr. Clair presented student prize membership awards to students from Swarthmore, Princeton University, Drexel Institute of Technology, University of Delaware, Lehigh University, Bucknell University, Lafayette College, University of Pennsylvania, and Philadelphia College of Textiles and Science.

MISSISSIPPI VALLEY

AT A JOINT meeting of the ASTM Mississippi Valley District and the Engineers Club of St. Louis on October 19, more than 100 members of these two organizations heard Executive Secretary T. A. Marshall, Jr., discuss the problems of the young engineer in planning his future.

In his talk, Mr. Marshall pointed out that there are four major questions which the young engineer should ask himself in planning for his future: (1) what do I want? (2) where can I find it? (3) what do I have to offer? and (4) what else do I need to get what I want? In discussing the first of these guides, Mr. Marshall explored the relative importance and merits of such goals as social prestige, job satisfaction, work enjoyment, and economic security. In discussing economic security, he pointed out that initiative, resourcefulness, and adaptability have been our greatest assets as a nation and urged the young engineers not to trade these assets for a liability. "Less emphasis now on security will make for more enterprise and initiative. In turn these bring greater returns and ultimately greater real security," he said.

As a second step in planning the young engineer's future, Marshall discussed the various opportunities that exist for the young graduate engineer and urged those present not to overlook the opportunities that may be found in the thousands of small plants throughout the country. He also urged the young engineers to continue their development and growth after graduation by active participation in one or more of the professional societies and by reading and study in other fields as well as in their specialty.

A highlight of the meeting, chaired by Allan M. Siegel, chairman of the Mississippi Valley District Council, and director of Industrial Testing Laboratories, Inc., of St. Louis, was the annual presentation of student prize membership awards to outstanding engineering students from the University of Missouri, Missouri School of Mines, St. Louis University, and Washington University of St. Louis. Chairman of the committee selecting the recipients was Reverend Victor J. Blum,

AT THE MISSISSIPPI VALLEY DISTRICT MEETING

(Left to right) A. W. Brust, professor of civil engineering, Washington University; Jack Rausch, district council secretary, Russell, Mulgardt, Schwarz, Van Hoefen, Architects; H. D. Comins, professor of civil engineering, University of Missouri; C. L. Wilson, dean, Missouri School of Mines and Metallurgy; ASTM Executive Secretary T. A. Marshall, Jr.; Rev. V. J. Blum, S.J., dean, Institute of Technology at St. Louis University; and A. M. Siegel, district council chairman, Industrial Research and Testing Laboratories, Inc.

S.J., dean of the Institute of Technology at St. Louis University. The students and their faculty sponsors were introduced by Father Blum. Prior to the meeting, the students were the guests of the Mississippi Valley District Council at a dinner at the Engineers' Club of St. Louis.

CENTRAL PLAINS

New District Organized

AT A MEETING on Wednesday, October 18, 1961, at the Wishbone Restaurant in Kansas City, Mo., a group of more than 20 members of the Society elected Walter Gubar of the Gustin-Bacon Manufacturing Co., Kansas City, Mo., provisional chairman of a new ASTM Central Plains District Council. At this meeting, attended by Executive Secretary T. A. Marshall, Jr., plans were made for the appointment of a nominating committee to prepare a slate of candidates for the new district council. Plans for a meeting to be held in the early spring of 1962 were also discussed.

James H. Bennett, Kansas City Junior College, was elected provisional secretary. The council *pro tem* chosen includes J. S. Rearick, C. W. Nofsinger Corp.; T. F. McMahon, University of Kansas; H. J. Gilkey, Iowa State University; F. E. Lormis, Bendix Corp.; Joseph Dixon, The Sheffield Steel Co.; and James Meyers, The Wichita Testing Laboratory.

The new Central Plains District will serve Nebraska, Iowa, Kansas, and western Missouri.

NORTHERN PLAINS

New District Organized

A NEW DISTRICT to serve North and South Dakota, Minnesota, and western Wisconsin was organized during a meeting in the Coffman Memorial Union Building at the University of Minnesota in Minneapolis on Tuesday evening, October 17, 1961.

This organization meeting was attended by more than 30 interested members of the Society, not only from the vicinity of the Twin Cities but also from Rapid City, S. Dak., and the northern reaches of Minnesota.

After discussion with Executive Secretary Marshall concerning the organizational details for a new Society district, the members present elected Walter A. Gammel, Sr., president, Modular Electronics, Inc., as provisional chairman. Emil Hargett, professor of civil engineering, South Dakota State College of Agriculture and Mechanic Arts, and John Engstrom, engineering standards manager, American Hoist and Derrick Co., were elected provisional vice-chairmen. C. E. Twitchell, Minnesota Mining and Manufacturing Co., was elected provisional secretary. A nominating committee composed of A. S. Bull of Minnesota and Ontario Paper Co. as chairman; W. M. Barnum of Northern States Power Co.; Sander G. Lawrence, Lerch Bros., Inc.; T. M. Thomas, Remington Rand Univac; and A. A. Blatherwick, University of Minnesota, was elected to prepare a slate of candidates for a permanent district council and officers of the new district. Preliminary plans were discussed for a meeting of the new Northern Plains District in Minneapolis in February, 1962. In addition to the provisional officers, the other members of the provisional District Council are: W. M. Barnum, Northern States Power Co.; P. R. Edmondson, Ancker Hospital and University of Minnesota; Stephen E. Erickson, The M. A. Hanna Co.; Albert C. Holler, Twin City Testing and Engineering Laboratories, Inc.; and Sander G. Lawrence, Lerch Bros., Inc.

NEW ENGLAND

NONDESTRUCTIVE CHEMICAL spot tests for quality control of metals were described by Benjamin B. Burbank, chief metallurgist, Bath Iron Works Corp., at a November 2 meeting of the New England District, jointly with the Boston Society of Civil Engineers, the New England Section of the American Society of Civil Engineers, and the Boston Section of the Society for Nondestructive Testing. Mr. Burbank gave detailed, step-by-step procedures for rapid tests that can be performed in the field using only a compact, portable kit of reagents. He illustrated the need for such tests by referrring to several case histories in which the unwitting use of the wrong material had resulted in expensive replacement and, in some cases, danger to operating personnel.

New England District Council Chairman F. J. Mardulier presided at the technical meeting, which was held at the Arnold Greene Testing Laboratories, in Natick, Mass., and which was preceded by a tour and demonstrations of the facilities at the laboratory and by a social hour and dinner. Nondestructive test techniques such as X-ray and gamma ray, magnetic particle, penetrant liquid, ultrasonic, and eddy current were demonstrated.

ASTM President Miles N. Clair greeted the gathering of approximately 135 on behalf of the Society and gave a brief description of the history and purposes of ASTM. He presented student prize membership awards to students from Worcester Polytechnic Inst., University of Massachusetts, Massachusetts Institute of Technology, University of Rhode Island, Brown University, University of New Hampshire, Norwich University, Lowell Technological Inst., Dartmouth College, Northeastern University, University of Vermont, University of New Hampshire, Tufts University, and University of Connecticut.

AT NEW ENGLAND MEETING

(Upper left) District Council Chairman F. J. Mardulier *(second from left)* discusses progress of meeting with *(from left)* James Brittain, president, Boston Society of Civil Engineers; C. B. Millard, chairman, Boston Section, Society for Nondestructive Testing; and J. H. Fullerton, president, New England Section, ASCE. *(Upper right)* three of those at the head table *(from left)*: W. L. Glowacki, secretary, and C. G. Johnson, vice-chairman, New England District Council of ASTM, and Mr. Brittain. *(Lower left)* Arnold Greene *(right)*, chairman of the program committee and host for the meeting, discusses laboratory facilities with a guest. *(Lower right)* Dr. Clair *(left)* greets the speaker for the evening, B. J. Burbank.

ACDA Approves Revised District Charter

FOREMOST ON the agenda of the Administrative Committee on District Activities at its November 1 meeting in Philadelphia was the approval of a revised District Charter and Manual of Operations. This was the first complete revision of the operating regulations for districts since 1947. The revised Charter and Manual have been forwarded to the Board of Directors for formal adoption. The Administrative Committee has spent 18 months in preparing the revisions. Highlights of the new regulations include granting to the districts more autonomy to run their own financial affairs, provisions for honorary membership in district councils, certain restrictions on who may serve as an officer of a district, elimination of staggered terms of office, and more detailed instructions on district management. After approval by the Board of Directors, the revised Charter and Manual will be printed and distributed to all district councilors and officers.

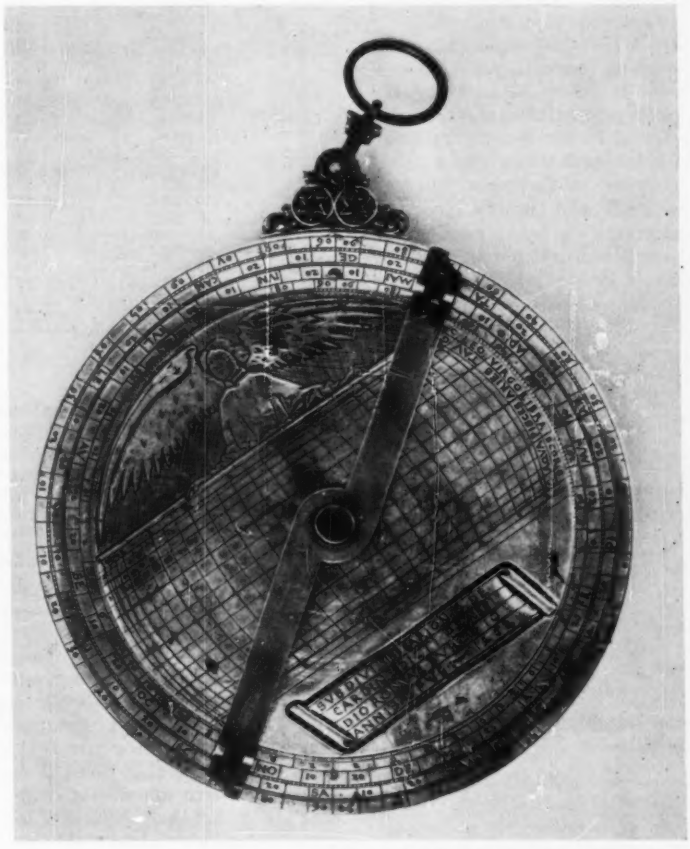
The Administrative Committee initiated several programs to assist the district councils. Among these is the preparation of a Manual for the presentation of student prize awards. A study of suitable promotional material for use in conjunction with the prize awards is also being made. Efforts will be made to have closer liaison between the technical committees and the districts for the purposes of promoting meetings and symposia. Also started is an investigation to determine whether or not districts would be feasible in Hawaii, Mexico, and a portion of eastern Canada.

Among the other plans that were formulated is a trial program of a study course in materials. This study course will be under the supervision of the Chicago District Council on an experimental basis. If successful, other districts will be invited to undertake similar programs in their areas. The exact details of the study course have not as yet been worked out, but it is hoped that the experimental program can begin in the fall of 1962.

An open meeting for all district officers and councilors will be sponsored by the Administrative Committee at the next annual meeting of the Society in New York, in June, 1962. The exact program, time, and place will be announced at a later date.

The Administrative Committee on District Activities will meet during Committee Week, and officers and councilors of the various districts are asked to communicate with the secretary of the committee if they have any problems or other matters which they believe the committee should consider.

The First Scientific Instrument of the Renaissance



National Maritime Museum, Greenwich, England

Johannes Müller (1436–1476) of Königsberg, called Regiomontanus, was the first astronomer to set about the serious business of escaping from the Middle Ages and restoring his science in keeping with the new traditions of the Renaissance. The book-loving Cardinal Bessarion brought him to Italy where he could have access to fine manuscripts of the classical astronomers. Later he returned to Nuremberg and set up there a printing press for scientific books and a workshop for the manufacture of scientific instruments. This astrolabe, now in the National Maritime Museum, Greenwich, England, appears to be one of the earliest and perhaps finest pieces of his work. It was made as a gift to his patron, Bessarion, carries the date 1462 in its dedicatory inscription, and includes a delicately engraved picture. This seems to be a portrait of the young Regiomontanus in the guise of an angel, spreading wings of learning over the world. This is the first instrument to break with medieval tradition in its style and scientific design.

Text by Professor Derek J. de Solla Price, Yale University. Copyright; text and photographs reproduced by permission of Professor Price and Arthur D. Little, Inc.

Temperature Susceptibility of Asphalt Bitumens

(*Continued from p. 982*)

generally confirmed that the C correction factor would not be required.

If Eq 1 holds for all asphalts over the usual working range, then the value B would be a numerical index of the temperature susceptibility of consistency (as measured by the penetration test). By Eq 1, the logarithm of the penetrations obtained at the same load and duration will plot against the test temperatures as a linear relationship. The slope, B, of this line would measure in each case the coefficient of temperature susceptibility for a specific bitumen. Its value will change dependent upon the type of product, method of manufacture, and origin of the bitumen.

Slope B from the plot is really:

$$B = \frac{d(\log_{10} P)}{dT} \quad \ldots\ldots\ldots (3)$$

which expresses change of penetration with temperature. But

$$\frac{d(\log_{10} P)}{dT} = \frac{\log_{10} e \dfrac{dP}{dT}}{P} \quad \ldots\ldots\ldots (4)$$

Therefore:

$$\frac{1}{P}\frac{dP}{dT} = \frac{B}{\log_{10} e} = 2.303\ B \quad \ldots\ldots\ldots (5)$$

Proposed Definition of Susceptibility

The expression $1/P\ (dP/dT)$, the fractional change of penetration per degree change in temperature, is a constant equal to 2.303 B, whereas the actual change in penetration between two temperatures, dP/dT, is a variable dependent upon the penetration level. Modification of the fractional change of penetration with temperature to the percentage change in penetration with temperature—that is, $100 \times 2.303\ B$—provides a better definition of susceptibility. However, for practical purposes the value of $100B$—defined as the "susceptibility index"—is recommended. The use of $100B$ eliminates multiplying by 2.303, which can lead to errors.

The value B is the slope obtained by plotting the logarithm of penetration against temperature, using the same load and test time for all penetration determinations. On the basis of measurement of penetration at two test temperatures:

$$B = \frac{\log_{10} P_{T1} - \log_{10} P_{T2}}{T_1 - T_2} \quad \ldots\ldots (6)$$

where T_1 and T_2 are the temperatures at which the penetration values P_{T1} and P_{T2}, respectively, were obtained. Since the value of B will be dependent upon the temperature scale used, Fahrenheit temperatures have been specified for this calculation.

TABLE II.—DETERMINATION OF SUSCEPTIBILITY INDEX FROM P_{T1}/P_{T2} RATIO.
(Applies only when interval between T_1 and T_2 is 23 F and penetrations are run at 100 g, 5 sec)

Ratio P_{T1}/P_{T2}	B Value	Susceptibility Index, (= $100B$)
1.6	0.0089	0.89
1.8	0.0111	1.11
2.0	0.0131	1.31
2.2	0.0150	1.50
2.4	0.0165	1.65
2.6	0.0180	1.80
2.8	0.0195	1.95
3.0	0.0207	2.07
3.2	0.0220	2.20
3.4	0.0231	2.31
3.6	0.0242	2.42
3.8	0.0252	2.52
4.0	0.0262	2.62
4.2	0.0271	2.71
4.4	0.0280	2.80
4.6	0.0288	2.88
4.8	0.0296	2.96
5.0	0.0303	3.03
5.2	0.0311	3.11
5.4	0.0318	3.18
5.6	0.0325	3.25
5.8	0.0332	3.32

Relationship Also Holds for Industrial Asphalts

The question was raised as to whether this relationship, historically affirmed for steam-reduced asphalts, would apply equally well to the air-blown, industrial-grade asphalts with which Committee D-8 is more directly concerned, and this has been proved by the laboratories cooperating in the program. Figures 2 and 3 illustrate some of the data that have been obtained. In all cases, the penetration test was run with a 100-g load and a test duration of 5 sec (Table I). Linear plots were always obtained except on a few asphalts when the penetration measurement was below 10—a level where it is difficult to make precise measurements.

Recommended Procedure

Based on these studies, the following procedure is recommended for measuring the temperature susceptibility of asphalt consistency:

Penetration tests (ASTM Method D 5) shall be run in the standard manner using a load of 100 g and a test duration of 5 sec. This shall be done for at least three different temperatures. It is recommended that these temperatures be 77 F (to define the grade), 100 F, and 54 F. The 23 F spacing is desirable for later calculation purposes.

Plot the data on semilog paper to ensure that the three values provide a smooth relationship. (This is desirable since the presence of additives, wax, etc., may affect the linearity of the relationship.)

Alternate 1.—Calculate the slope, B, from the smooth plot using Eq 6. The susceptibility index is 100 B.

Alternate 2.—When the temperatures are spaced at 23 F intervals, the susceptibility index can be obtained from the ratio of penetration 1 to penetration 2 at temperatures T_1 and $(T_1 - 23\ \text{F})$ using Table II. This will not necessarily be as precise as by the method of Alternate 1.

Specifications for different products can then be set using the penetration 77 F (100 g, 5 sec) for the grade and a minimum and maximum index to define the desired temperature susceptibility.

Currently this recommendation applies only to asphaltic-base bitumens. Further studies are being made of the industrial-grade coal-tar pitches to determine if the same method can be used. In the past, the penetration test has not been part of the specifications for this class of material.

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BOOKSHELF

Members who wish to be considered for reviewing books are invited to send in their names and subjects in which they are interested. Due to customs and mailing considerations, requests from the United States only can be considered. Copies of these books are not available through ASTM: all inquiries concerning them should be addressed to the publisher.

Metallic Fatigue

By W. J. Harris; Pergamon Press Ltd., New York, N. Y. (1961); 331 pp.; $12.50.

Reviewed by F. B. Stulen, Curtiss-Wright Corp., Caldwell, N. J.

THIS EXCELLENT BOOK on the fatigue of metals should be read by every engineer, designer, and metallurgist dealing with high-performance machinery and structures. More a reference work than a textbook, it discusses in some detail many of the important factors that affect the fatigue life of machinery and structures in service, arranged in a logical sequence. There is a considerable amount of experimental fatigue information, much of which was generated in the author's laboratories.

Not only does the author present a large amount of experimental data, but he also presents the fundamental aspects of some of the fatigue phenomena, such as notch sensitivity, corrosion fatigue, fretting fatigue, and crack propagation.

The first chapter discusses stress-concentration factors and notch sensitivity. In this chapter the author proposes a new explanation of notch sensitivity. In the second chapter, "The Alleviation of Stress Concentration," various process methods of reducing the effect of stress concentrations are described, and fatigue data showing the relative improvement to be expected by each process are included.

The third chapter, "Frequency," considers the effect of frequency and the interrelation between frequency and corrosion. Here several high-frequency pneumatic-type exciters are described that are used in the author's laboratory and are adaptable to the testing of a wide variety of components.

The next two chapters consider the effects of corrosion and fretting, which are known to cause very serious losses of the fatigue strengths of components in service. Although the effect of corrosion is well known, many designers are not aware of the deleterious effect of fretting, which can readily occur in any type of mechanical connection. In these chapters, the author discusses some of the fundamental aspects of corrosion and fatigue and describes methods of minimizing fretting.

The modern view of cumulative fatigue damage is that it is closely associated with crack propagation and initiation. Chapter VI, "Crack Propagation," begins with the important difference between the "safe-life" design philosophy and the "fail-safe" design philosophy. This chapter summarizes some of the existing data on the "critical crack length" and the rate of crack propagation in fatigue. Some of the fundamental concepts in crack propagation are presented.

In Chapter VII, the statistical distributions (Freudenthal, Weibull, and log-normal) that are used in the analyses of fatigue are summarized.

In the last chapter, the author discusses many types of surface treatments, particularly platings, and their effect on fatigue.

Although most of the important aspects of fatigue are included in this book, there are certain subjects that are either not included or have little coverage in the book. Some of these are (1) effect of steady stresses, (2) cumulative fatigue damage, (3) treatment of acoustic fatigue, (4) size effect, (5) effect of inhomogene-

(*Continued on p. 1014*)

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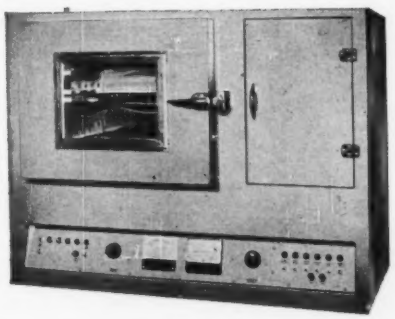

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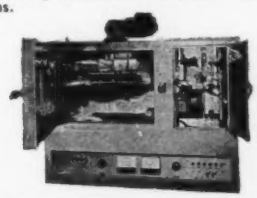

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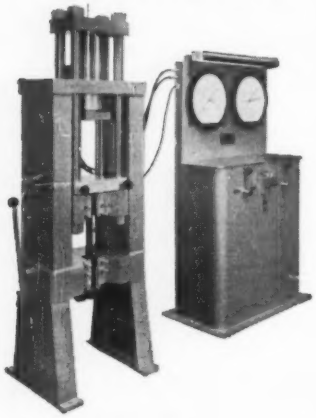

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BOOKSHELF

(*Continued from p. 1013*)

ieties, (6) anisotropy effects, (7) the relation of fatigue to other physical properties, and (8) methods of design, etc. However, it is probably impracticable to cover all these additional subjects under one cover.

Unfortunately, there is some inconvenience for the engineer in the United States in converting tons per square inch to pounds per square inch and in the unfamiliarity of many British alloy and process designations.

There is an adequate subject and author index.

This book is a valuable contribution to the field of fatigue, and contains a number of new theoretical concepts that are important for the fundamental understanding of this major problem in engineering design.

Flow of Fluids Through Porous Materials

R. E. Collins; Reinhold Publishing Corp., New York, N. Y. (1961); 290 pp.; Illus.; $12.50.

Reviewed by L. C. Gilbert, ASTM Staff.

THE FLOW of fluids through porous materials is of importance in many fields of engineering. A recent application is the proposal to dispose of atomic wastes by injecting them into depleted oil reservoirs. Although this volume is for general use, it has been designed primarily for the petroleum reservoir engineer or research worker in petroleum production.

Extensive treatment is given of the physical properties of porous materials. The theory of various types of flow is developed and applications are presented. The advanced mathematical concepts needed for theoretical treatment are developed and explained.

This book should be of interest to chemical and civil engineers and soil scientists.

CALENDAR

Dec. 27–30—**American Statistical Association and Institute of Mathematical Statistics,** 121st Annual Meeting, Roosevelt Hotel, New York, N. Y.

Jan. 8–12—**Society of Automotive Engineers,** Annual National Automotive Engineering Congress and Exposition, Cobo Hall, Detroit, Mich.

Jan. 9–11—**American Institute of Electrical Engineers, Institute of Radio Engineers, American Society for Quality Control, and Electronic Industries Association;** 8th National Symposium on Reliability and Quality Control; Statler-Hilton Hotel, Washington, D. C.

Jan. 15–18—**National Concrete Masonry Association,** 42nd Annual Convention, Americana Hotel, Bal Harbour, Fla.

Jan. 22–24—**Institute of the Aerospace Sciences,** 30th Annual Meeting, Hotel Astor, New York, N. Y.

Jan. 24–26—**The American Society of Mechanical Engineers,** Heat Transfer Division, Second Symposium on Thermophysical Properties, Princeton University, Princeton, N. J.

Jan. 25–27—**National Society of Professional Engineers,** Winter Meeting, King Edward Hotel, Jackson, Miss.

Jan. 29–31—**Association of Asphalt Paving Technologists,** 36th Annual Meeting, Sheraton-Charles Hotel, New Orleans, La.

Jan. 29–Feb. 1—**American Society of Heating, Refrigerating and Air-Conditioning Engineers,** Semi-Annual Meeting, Chase-Park Plaza Hotel, St. Louis, Mo.

Jan. 29–Feb. 2—**American Institute of Electrical Engineers,** Winter General Meeting and Electrical Engineering Exposition, New York Coliseum and Hotel Statler, New York, N. Y.

Jan. 30–Feb. 2—**Society of Plastics Engineers,** 18th Annual Technical Conference, Penn-Sheraton Hotel, Pittsburgh, Pa.

Feb. 4–7—**American Institute of Chemical Engineers,** National Meeting, Hotel Statler-Hilton, Los Angeles, Calif.

Feb. 5–9—**National Sand and Gravel Association and National Ready Mixed Concrete Association,** 32nd Annual Convention and Biennial Show, Conrad Hilton Hotel, and McCormick Place, Chicago, Ill.

Feb. 10–14—**Mason Contractors Association of America,** Annual Convention and Show, Shamrock Hotel, Houston, Tex.

Feb. 12–14—**National Concrete Products Association,** 13th Annual Convention, Sheraton-Brock Hotel, Niagara Falls Ont., Canada.

Feb. 12–15—**Air-Conditioning and Refrigeration Institute,** 12th Exposition of the Air-Conditioning, Heating and Refrigeration Industry, Great Western Exhibit Center, Los Angeles, Calif.

Feb. 18–22—**American Institute of Mining, Metallurgical, and Petroleum Engineers,** Annual Meeting, New York, N. Y.

Feb. 18–22—**American Institute of Electrical Engineers and American Institute of Mining, Metallurgical, and Petroleum Engineers,** 4th National Electrical Insulation Conference, Shoreham Hotel, Washington, D. C.

Feb. 18–22—**Technical Association of the Pulp and Paper Industry,** Annual Meeting, Commodore Hotel, New York, N. Y.

Feb. 26–Mar. 1—**National Concrete Masonry Association,** 42nd Annual Convention, Dallas, Tex.

Feb. 27–Mar. 1—**The Society for Nondestructive Testing, Inc.,** 3rd Annual Symposium on Nondestructive Testing of Aircraft and Missile Components, Gunter Hotel, San Antonio, Tex.

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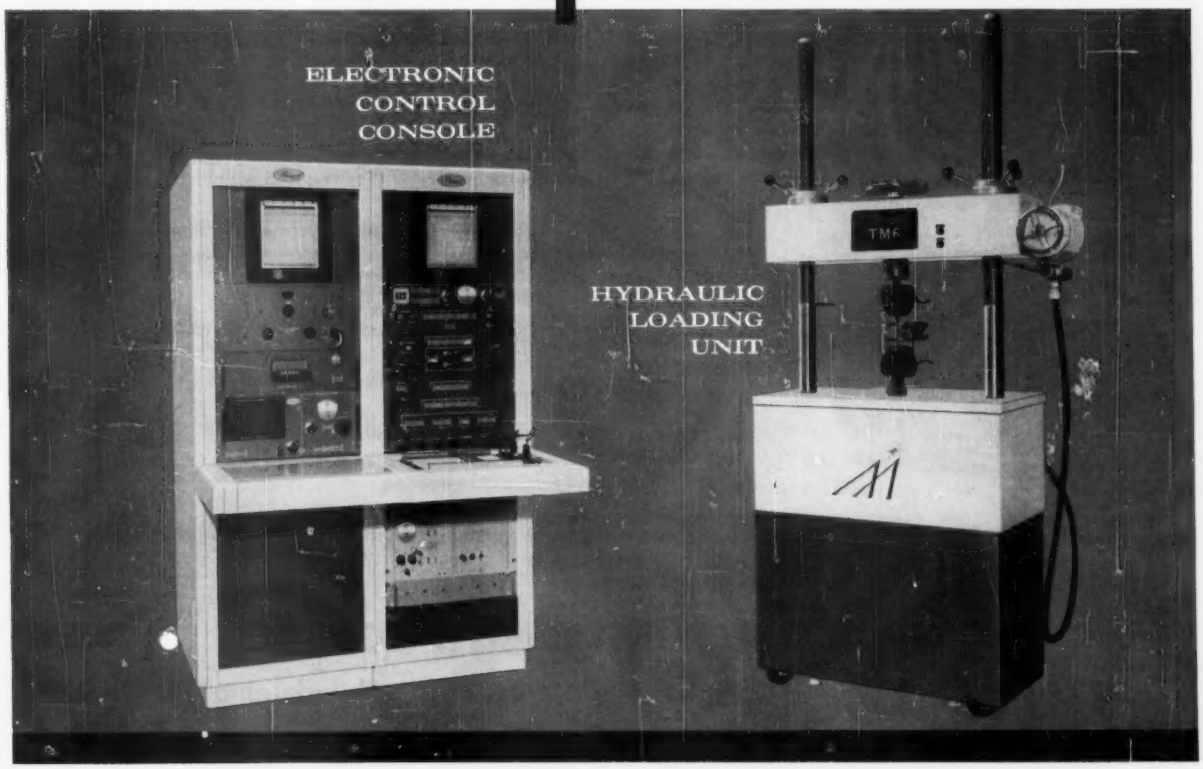

FOR FURTHER INFORMATION CIRCLE 1362 ON READER SERVICE CARD

MATERIAL QUESTIONS

NEARLY EVERY DAY the mail at ASTM Headquarters includes some questions about materials, specifications, test methods, or related problems. We feel that the answers, many of which are based on information given us by officers of committees in their capacity as committee officers, are of general interest. For the most part inquiries we receive relate to the activities of the Society, either standards, research work, or publications. Often, an inquiry is such that the services of a consultant or independent testing laboratory are obviously required; in this event we do not hesitate to so recommend.

Use of Tentatives

What is the difference between an ASTM standard and a tentative?

●All ASTM methods of tests, specifications, and definitions of terms, are in most every case accepted first as a tentative. However, an item may be submitted for immediate adoption as a standard, if so desired by the committee. After a minimum period of one year, a tentative may be advanced to standard, bearing the same designation. To identify the tentative, the letter "T" is placed at the end of the designation, for example, D 1561 – 58T.

Tentatives are developed in the same manner as standards in the technical committee. When presented to the Society, the tentative is approved at the Annual Meeting by voice vote or may be approved during the year by the Administrative Committee on Standards. The advancement of a tentative to standard, or the immediate adoption of a standard, can only be recommended at the Annual Meeting subject to confirming letter ballot of the Society.

The acceptance and recognition of tentatives vary among industries. In many cases, the tentative is used on the same basis as a standard in contracts and specifications. The purpose of the tentative is to provide a document for use pending adoption as standard. During this period, suggestions for revisions are encouraged. When received, these are referred to the responsible committee for review and consideration. It is the policy of the Society to submit tentatives to the American Standards Assn. for approval as American Standard subject to the preliminary approval of the responsible committee.

Floor Covering Materials

We note there is no section dealing with floor covering materials in the Book of ASTM Standards. Are there any ASTM specifications covering vinyl asbestos, asphalt, cork, or linoleum floor surfaces?

●There are no ASTM standards in this field. A few years ago the Society conducted a study to determine the need for standards for resilient floor coverings which included conferences with both manufacturers and consumers. It became apparent that the manufacturers did not feel the need for ASTM standards, although the consumers expressed the opposite point of view. It is necessary to have the full support of industry in ASTM standardization activities, and, therefore, no work has been done. The subject has not been dropped; it is now being reviewed. Comments on the interest in ASTM standards in this field are welcome.

Plumbing Code and Plumbing Materials

Would you please forward standards on plumbing?

●We receive numerous inquires from the plumbing trade and from code authorities as to the availability of ASTM specifications covering the various materials used in plumbing installations. There are 26 ASTM specifications covering such pipe and tubing materials as clay, concrete, asbestos-cement, bituminized-fiber, brass, copper, nickel, steel and cast iron; pipe fittings; brass, copper, and steel plate, strip, and bars; and solder metal.

Attention is also called to an American Standard known as the National Plumbing Code (ASA A40.8). This publication contains full reference to the above specifications.

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OTS REPORTS

THESE reports, recently made available to the public, can be obtained from the Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C. Order by number.

Corrosion

Environmental and Metallurgical Factors of Stress-Corrosion Cracking in High-Strength Steels, *AD 254 941*, 75 cents.

Stress-Corrosion Cracking—A Nontechnical Introduction to the Problem, *AD 250 167*, 75 cents.

The Corrosion of Aluminum Alloys in High-Velocity Water at 170 to 290 C, *ORNL-3063*, 75 cents.

The Corrosion of Aluminum Alloys in the Oak Ridge Research Reactor, *ORNL-3151*, 75 cents.

Summary Report on The Corrosion of Aluminum in High-Temperature Water Systems, *HW-59778 REV*, 50 cents.

Film Growth on Aluminum in High-Temperature Water, *ANL-6230*, 50 cents.

Electrical Resistance Studies of Anodic and Corrosion Oxide Films Formed on Zirconium, *ANL-6259*, 75 cents.

Metals

On the Mechanism of Yield and Flow in Iron, *NAA-SR-5838*, 75 cents.

Brazing for High-Temperature Service, *PB 151 108*, $1.

Welding of Boron Stainless Steel Control Rods, *ACNP-6106*, 50 cents.

The Emittance of Stainless Steels, *AD 259 283*, 50 cents.

Review of Recent Developments in The Metallurgy of High-Strength Steels, *AD 259 986*, 50 cents.

Bending Methods for Stainless Steel Tubing, *PB 151 109*, $1.50.

A Flux-Free Method for Joining Aluminum to Stainless Steel, *HW-68789*, 50 cents.

Ultra-Short-Time Creep Rupture, *PB 171 947*, $2.25.

Tension, Torsion, and Column Properties of Commercially Pure Titanium Tubing at Room Temperature, *PB 171 882*, 75 cents.

The Effects of Alloying Elements in Titanium, *AD 260 226*, $3.

Statistical Analysis of Tensile Properties of Heat-Treated Ti-4Al-3Mo-1V and Ti-2.5Al-16V Sheet, *AD 259 284*, $1.25.

Review of Recent Developments on Oxidation-Resistant Coatings for Refractory Metals, *AD 255 278*, 50 cents.

Review of Recent Developments in The Technology of Nickel-Base and Cobalt-Base Alloys, *AD 255 659*, 50 cents.

Problems of Metallography and The Physics of Metals (USSR) (Part I–337 pages; Part II–383 pages), *61-11156*, $7 for both.

Miscellaneous

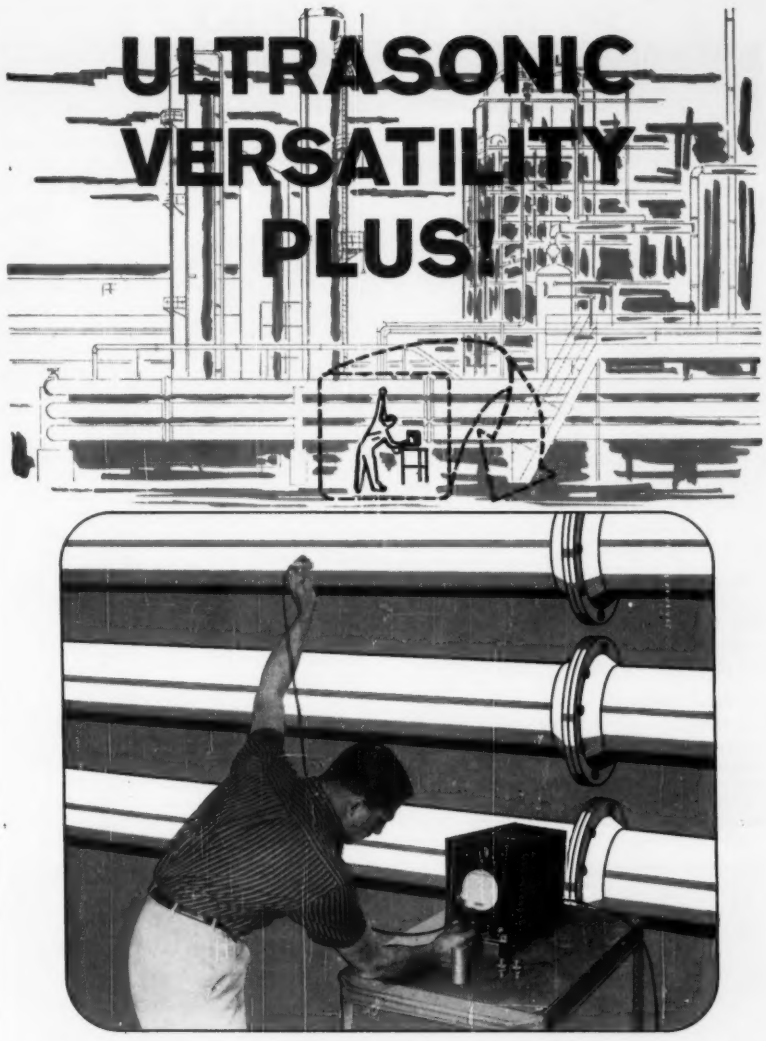
Supplement No. 3, Patent Abstract Series (July 1958 through December 1960) Instrumentation, *PB 171 672*, $1.

Chemical Products and Processes, *PB 171 673*, $1.50.

Metal Processes and Apparatus, Machinery and Transportation Equipment, *PB 171 675*, $1.25.

Electrical and Electronic Apparatus, *PB 171 676*, $1.75.

Ceramic, Paper, Rubber, Textile, Wood and Other Products and Processes, *PB 171 678*, 50 cents.



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NEWS OF MEMBERS

Ludwig Adams has rejoined the Pittsburgh–Des Moines Steel Co., Pittsburgh, Pa., as assistant chief engineer, cryogenics. He will continue as vice-president and director, Virginia Electron Corp., an affiliated company.

Robert C. Adler is now a member of the development engineering staff, Aeroquip Corp., Jackson, Mich. Formerly he was structural engineer, Substation Design Section, Electrical Engineering Dept., Commonwealth Associates, Inc., Jackson, Mich.

Herbert C. Arlt, Bell Telephone Laboratories, Inc., Murray Hill, N. J., was named Fellow of the Standards Engineers Society for his outstanding service in all aspects of standardization. Mr. Arlt is a past-president of SES.

Merton M. Beckwith has been named vice-president and technical director, R. O. Hull & Co., Inc., Cleveland, Ohio. Dr. Beckwith had been with The Harshaw Chemical Co., Cleveland, Ohio.

Earle S. Bidgood, previously supervisor, Superior Tube Co., Phoenixville, Pa., is project leader, Pennsalt Chemicals Corp., King of Prussia, Pa.

Arthur Bloomberg, previously statistician, General Instrument Co., Semiconductor Div., Hicksville, N. Y., is serving in the same capacity in the Quality Control Dept., Hercules Powder Co., Rocky Hill, N. J.

Merwin Brandon, president, Underwriters' Laboratories, Inc., Chicago, Ill., received a gavel and plaque from members of the Correlating Committee of the National Electrical Code Committee for his outstanding leadership as chairman of this committee. This committee is responsible for the preparation of the National Electrical Code.

Arthur F. Brown, president, Imperial Color Chemical and Paper Corp., Glens Falls, N. Y., retired recently. Mr. Brown received a Forty-Year Membership Certificate at the Society's 64th Annual Meeting in June.

Malcolm M. Clark, formerly laboratory supervisor, Dumont Manufacturing Corp., San Rafael, Calif., is now production manager, Monitor Plastics Co., San Rafael, Calif.

Edward L. Criscuolo, technologist, U. S. Naval Ordnance Laboratory, Silver Spring, Md., received the Coolidge Award from the Society of Nondestructive Testing at the Honor Session of the Society's 21st Annual National Convention.

Richard L. Davis is now with Koppers Co., Inc., Pittsburgh, Pa., as a chemical engineer. Formerly he was a consulting engineer with Miller-Warden Associates, Swarthmore, Pa.

R. P. Dinsmore, vice-president in charge of research and development, Goodyear Tire & Rubber Co., Akron, Ohio, retired recently. Mr. Dinsmore represented his company on Committee D-11 on Rubber and Rubber-Like Materials since 1926.

J. H. Foote, one of our most active members, retired December 1, 1961, as chief engineer, Commonwealth Associates, Inc., Jackson, Mich. Mr. Foote has been a member of Committee B-1 on Wires for Electrical Conductors since 1933, which committee he served as secretary from 1934 to 1938 and chairman from 1938 to 1950. He has also served on Committees A-5 on Corrosion of Iron and Steel, E-5 on Fire Tests, and the Administrative Committee on Standards, recently as chairman. Other activities include ASA Council, ASA Electrical Standards Board, and the U. S. National Committee of the International Electro Technical Commission. Mr. Foote served on the ASTM Board of Directors from 1942 to 1944 and from 1946 to 1949. He is currently a member of the ASA Board of Directors.

William L. Foy, technical director, Foy Paint Co., Cincinnati, Ohio, was installed as the 40th president of the Federation of Societies for Paint Technology during the Federation's Annual Meeting in Washington, D. C.

Walter A. Gammel is now president, Modular Electronics, Inc., Oesseo, Minn. He had been president, Walter A. Gammel, Sr., and Associates, Brooklyn Park, Minn.

George Gleeson, dean, School of Engineering, Oregon State College, Corvallis, Ore, is the new president of Oregon Research Associates, Inc., a nonprofit corporation formed to expand research activity in the state.

D. W. Hange is assistant structural engineer, Los Angeles City School District, Architectural Design Branch, Los Angeles, Calif. He had been highway engineer, U. S. Forest Service, Nevada City, Calif.

R. A. Johnson is now chief chemist, Ohio Adhesives Corp., New Philadelphia, Ohio. Formerly he was senior chemist, Pittsburgh Corning Corp., Port Allegany, Pa.

D. E. Jones, chief chemist, American Hard Rubber Co., Butler, N. J., retired November 30, 1961. Mr. Jones represented his company in Society membership and on Committee D-11 on Rubber and Rubber-Like Materials.

James R. Lampman, manager, Organic Chemical Engineering Materials and Process Laboratory, General Electric Co., Syracuse, N. Y., has been elected president of the Society of Plastics Engineers for 1962. Mr. Lampman is a member of ASTM Committee D-9 on Electrical Insulating Materials.

(*Continued on p. 1020*)

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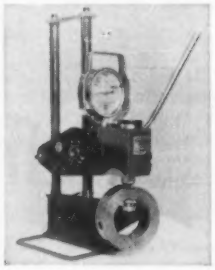

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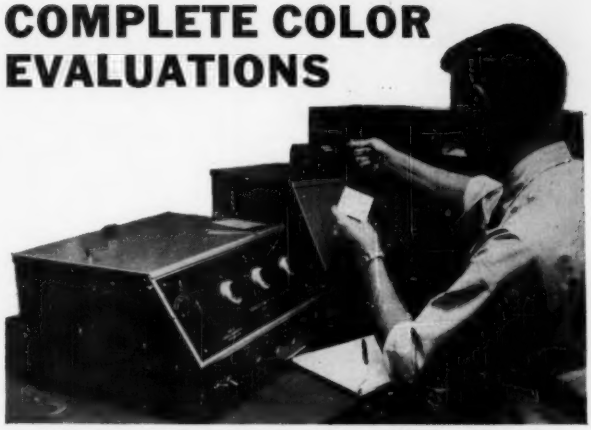

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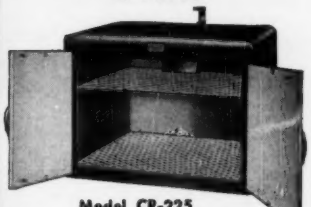

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CIRCLE 1369 ON READER SERVICE CARD

NEWS OF MEMBERS

(*Continued from p. 1018*)

Hao Wen Liu is a research fellow, Guggenheim Aeronautical Laboratory, California Institute of Technology, Pasadena, Calif. He had been research assistant professor, University of Illinois, Urbana, Ill.

Warren J. McGonnagle has joined Southwest Research Inst., San Antonio, Tex., as assistant director, electronics and electrical engineering. Previously he was associate physicist, Argonne National Laboratory, Argonne, Ill.

William H. McKinney, chief chemist, Koppers Co., Inc., Oil City, Pa., resigned recently. Mr. McKinney plans to move to Australia, and after he is settled he also plans to resume his activities in the Society.

Ray Morales is instructor, civil engineering, California State Polytechnic College, Pomona, Calif. He had been assistant civil engineer, Department of Water and Power, Los Angeles, Calif.

Wesley Grigg Mullen, formerly instructor, Civil Engineering Dept., University of Maryland, College Park, Md., is now serving in the same capacity at Purdue University, Lafayette, Ind.

Nathan M. Newmark, head, Civil Engineering Dept., University of Illinois, Urbana, Ill., received the 1961 Vincent Bendix Award of the American Society for Engineering Education.

Harry Rasmussen retired recently as manager, Mooney Div., Scott Testers, Inc., Providence, R. I. Mr. Rasmussen was a member of Committee D-11 on Rubber and Rubber-Like Materials since 1947.

John Rice, previously engineer, Merritt-Chapman & Scott Corp., New York, N. Y., is now engineer, Powers and Associates, Iowa City, Iowa.

George W. Robbins, a member of ASTM since 1940, retired recently from the Asphalt Sales Dept., Texaco, Inc., New York, N. Y. Mr. Robbins was active for 20 years in Committees D-4 on Road and Paving Materials and D-8 on Bituminous Materials for Roofing, Waterproofing, and Related Building or Industrial Uses. He served as secretary of Committee D-8 from 1950 to 1960, and in recognition of his contributions to the work of the committee he was elected an Honorary Member of the committee.

H. F. Wakefield, Union Carbide Plastics Co., New York, N. Y., retired September 30. Mr. Wakefield represented his company on Committee D-14 on Adhesives.

Maw Shiu Wang has joined the Monsanto Chemical Co., St. Louis, Mo., as research chemist, Analytical Section. Previously he was research associate in agronomy, University of Illinois, Urbana, Ill.

W. W. Wentz, chief, specifications section, Metallurgical Div., Aluminum Company of America, Pittsburgh, Pa., retired October 1, 1961. Mr. Wentz joined the Society in 1956 and was a member of Committee B-7 on Light Metals and Alloys, Sectional Committee on Safety Code for Ladders (ASA Project A 14), and ASTM Ordnance Advisory Committee.

Frank B. Whalen has joined Texas Instruments, Inc., Dallas, Tex., as associate engineer. Formerly he was administrative and project engineer, Lone Star Boat Co., Plano, Tex.

John A. Wickett, previously with Refractories Div., H. K. Porter Co., Inc., Pittsburgh, Pa., is now assistant editor, *Chemical Processing,* Putnam Publishing Co., Chicago, Ill.

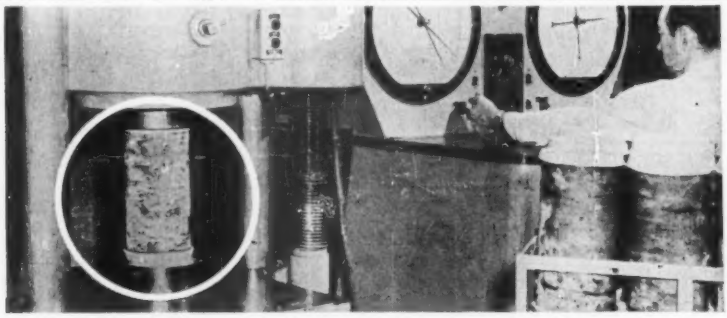
Theodore W. Van Zelst, president, Soiltest, Inc., Chicago, Ill., was elected a director of the Cenco Instruments Corp., of which Soiltest is a subsidiary.

DEATHS

Samuel Jacobsohn, president and chief physicist, The Gaertner Scientific Corp., Chicago, Ill. (October 5, 1961). Dr. Jacobsohn had represented his company in Society membership since 1949 and served on Committee E-2 on Emission Spectroscopy from 1932 to 1951.

E. G. Olds, Carnegie Institute of Technology, Pittsburgh, Pa. (recently). Professor Olds had been a member of Committee E-11 on Quality Control of Materials since 1946.

Frank B. Tarrant, president, Tidewater Coal Inspection Bureau, Inc., Norfolk, Va. (October 24, 1961). Mr. Tarrant represented his company in Society membership.



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First AASHO Road Test Report Now Available

THE FIRST of a series of reports on the results of the recently concluded road test of the American Association of State Highway Officials is now available from the National Academy of Sciences–National Research Council. Its title: "The AASHO Road Test: History and Description of Project," *Special Report 61A.*

This first report describes the history and development of the project, describes the test facilities and procedures, and sets the stage for later reports, which will describe materials of construction of the test road, operation of traffic, research on flexible and rigid pavement sections and on bridges, and special studies.

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MATERIALS AND TESTING TOPICS

This information is based on literature and statements from apparatus manufacturers and laboratory supply houses. The Society is not responsible for statements advanced in this publication.

FOR THE LABORATORY

Vibration Tester.—Test engineers, subjecting components or products to vibration fatigue tests, recognize the need for both true horizontal and true vertical movements in pinpointing possible mechanical defects. As a companion to an improved All American 150-lb horizontal testing machine recently announced, the company now has in production an improved vertical test unit. Machine is rated to produce 10 *g* with a 150 lb table load. Maximum capacity is approximately 23 *g*.

All American Tool & Mfg. Co. **3971**

Crystal Puller—A new laboratory model, the Czochralski-type crystal puller, is designed to meet the requirements of the solid-state research and development engineer or scientist for the growing and pulling of elemental and compound semiconductor materials.

Allen-Jones, Inc. **3972**

Dielectric Tester—The Model 4712 Hypot materials tester, for determining dielectric strength of insulating liquids, solids, and sheets at potentials to 60 kv, has an oil-sample test fixture complete with disk, mushroom electrodes, and gap gages to meet United States, English, and German test specifications.

Associated Research, Inc. **3973**

Humidity Indicator—A portable, compact, battery-powered psychrometer designed for quick determination of true relative humidity is introduced for general commercial and industrial use. Readings of wet and dry bulb can easily be taken in close proximity to critical manufacturing processes or in inaccessible locations and storage places. Accurate measurements may be made with the instrument in any desired position.

Better Fabrics Testing Bureau, Inc. **3974**

Ion-Exchange Materials—A new family of ion-exchange materials, analytical-grade ion-exchange crystals, inorganic microcrystalline aggregates with ion-exchange capacities, and properties similar to those of conventional ion-exchange resins are being offered. Showing extremely high selectivities for alkali metals and alkaline earths, the new family of crystals can be used in areas not covered by ion-exchange resins.

BIO-RAD Laboratories **3975**

Saturable Reactor—As a self-contained, convenient package, this Power-O-Matic 60 saturable reactor operates without contacts, switches, moving parts, potentiometer sliders, or photo cells, etc., usually associated with on-off cycling-type control systems. Straightline, stepless, and switchless, it has an infinitely proportional wattage control; temperatures are consistently repeated throughout entire unit range.

Blue M Electric Co. **3976**

Radiation Demonstrator—This is a new, portable, lightweight, fully transistorized radiation detection instrument for education and industry. It gives visible and audible indication of radiation and can demonstrate the statistical nature of the frequency of particle emission, the dependency of the detected radiation on the distance from the source, and the absorption of different types of radiation by various materials.

Central Scientific Co. **3977**

Refrigerated Centrifuge—An improved refrigerated centrifuge called the 20R centrifuge provides automatically controlled centrifugation at temperatures down to −20 C. Maximum speeds of 6000 rpm are readily secured, and much higher

(*Continued on p. 1024*)

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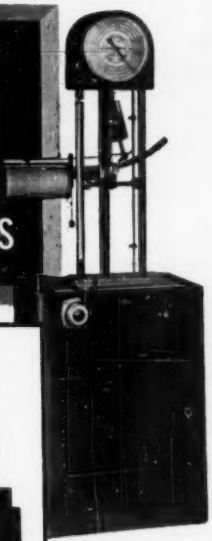

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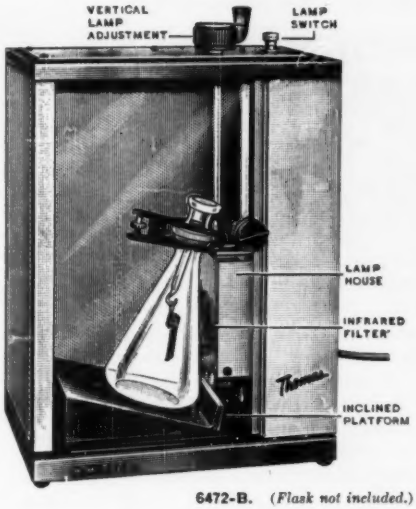

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OXYGEN FLASK SAFETY IGNITER,* Thomas-Ogg. For combustion of organic materials in a closed oxygen flask completely shielded within a safety cabinet. Utilizes a focused infrared beam from a built-in 150-watt lamp and special black paper sample wrappers for rapid ignition in an oxygen-charged clamp-closed flask. Vertical alignment of the sample in the beam, and push-button firing are done from outside the cabinet after door is fastened.

Cabinet is of metal, 12¼ × 8 × 16 inches high overall, with transparent acrylic plastic door with full-length hinge, baffled vents and spring-loaded latch. Lamp is mounted in housing with screw crank elevating device; fixed focusing reflector is sealed within lamp envelope. Inclined platform tilts flask to bring sample close to lamp.

6472-B. Safety Igniter, Thomas-Ogg, as described with flask platform, infrared filter, 100 black paper sample wrappers, extra lamp bulb, 3-wire cord, 3-prong plug with adapter and directions for use, but without combustion flask. For 115 volts..... **165.00**

6471-P10. Oxygen Combustion Flask,* Thomas-Ogg, of borosilicate glass, conical, 500 ml capacity. With ball-and-socket stopper held securely by Thomas Pinch Clamp. Stopper can be tilted to permit easy release of vacuum after combustion. With clamp and platinum sample carrier..... **41.70**

*Patent applied for. Based on developments by Clyde L. Ogg and associates, East. Util. Res. & Dev. Div., A.R.S., U.S.D.A., Phila., Pa.

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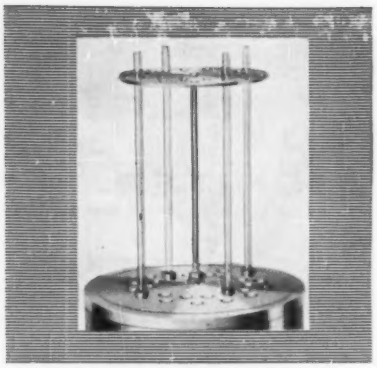

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FOR COMPLETE FACTS on the Scott Model LG with attachments for immersion testing, or standard Model LG for test tube aging, write to Scott Testers, Inc., 120 Blackstone St., Providence, R. I. Tel. DExter 1-5650 (Area Code 401).

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FOR THE LABORATORY

(*Continued from p. 1022*)

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Chicago Surgical & Electrical Co. **3978**

Temperature Chamber—A new temperature chamber is engineered to hold three modules capable of testing 150 component parts simultaneously over a range of −100 to 350 F. Model SU-100-10-HC, 10-cu-ft stainless steel chamber is especially adapted to nondestructive as well as life testing of diodes, resistors, capacitors, transistors, and other component parts.

Cincinnati Sub Zero Products **3979**

pH Buffer—Coleman certified buffer powders introduced for use in chemical laboratories are for preparing standard solutions for pH measurement. The powdered buffers permit the preparation of a convenient amount of buffer solution merely by adding the chemical formulation contained in a single packet to 100 ml of distilled water.

Coleman Instruments, Inc. **3980**

Transducer—Accurate recording of linear motion, force, acceleration, pressure, and other quantities measurable with differential-transformer transducers is achieved with the new Model 201AH transducer exciter-demodulator. The completely transistorized instrument provides 3-kc transducer excitation and demodulates the transducer signal to give an output signal suitable for input to servo systems, recording oscillographs, digital voltmeters, oscilloscopes, or computer systems.

Daytronic Corp. **3981**

Tester—A new testing machine for conducting tensile, transverse, and compression tests is the hydraulically powered Model UT-6 with two independent load-operating systems. The low-range system operates up to 10,000 lb. The high-range system goes up to 60,000 lb, 50 per cent greater than previous models. This double set of systems insures fine accuracy in the low-load area.

Detroit Testing Machine Co. **3982**

Microscope—For the critical checking of leading and trailing edges of turbine and compressor blades, the blade edge microscope is now equipped with new twin illuminators. This increased illumination throughout the optical system improves its use in full daylight and increases the clarity of the image.

Engis Equipment Co. **3983**

Fiber-Tester—A new high-speed tester for determining the tensile properties of single fibers at elongation rates in excess of one million per cent per minute is announced.

Fabric Research Laboratories, Inc. **3984**

Sampler—The Gelman phototape sampler completely eliminates the manual collection and evaluation of samples of dust from the air and is ideally suited for many gas-sampling and determination applications. It automatically collects samples on a paper tape, evaluates, and permanently records the concentration of dust or gas on a strip chart.

Gelman Instrument Co. **3985**

Interference Objective—A microscope objective for the examination of most reflecting surfaces by reflected light at approximately 100× total magnification produces an interference fringe pattern on the specimen corresponding to the variations in height of the surface. Although designed for use with Watson microscopes, it is contained within a simple unit which can be fitted to almost any microscope having a standard rms objective thread.

Wm. J. Hacker & Co., Inc. **3986**

Power Supply—A new d-c power supply, Model 723A, whose output can be programmed by external resistance for fast repetitive testing provides a regulated, continuously variable 0 to 40 v d-c output that can be changed with a front panel control or with an external resistance at a 50 ohms per v rate. Full-load output current is 500 ma over the entire voltage range, and a variable current-limit control (60 to 600 ma) protects test circuits from damage.

Hewlett-Packard Co. **3987**

Vacuum System—A new ultrahigh vacuum system is capable of achieving an ultimate pressure as low as 1×10^{-10} mm Hg and maintaining this pressure over a period of several days without the use of liquid helium. A pressure in the 10^{-9} mm Hg range can be attained within 4 hr from the start of pump-down operation, and a pressure in the low 10^{-10} mm Hg range can be reached after less than 8 hr.

Ilikon Corp. **3988**

Salt Mix—A simulated sea salt mix, known as Sea-Rite salt, is said to contain elements found in natural sea salt in quantities greater than 0.0004 per cent. The salt is granular and colorless with particles no larger than will pass through a 24-mesh screen. Adding about 4½ oz of Sea-Rite salt to a gallon of water produces a solution having a density equal to that of sea water, according to the company; it is useful in corrosion studies.

Lake Products Co., Inc. **3989**

Shaker—A new shaker, using the first major design change in the relatively short history of electrodynamic shakers, is capable of vibrating a 100-lb package to 100 *g*. The new shaker, Ling Model L-200, is rated at 22,000-lb force and is capable of taking medium-size test packages to high *g* levels.

Ling-Temco-Vought, Inc. **3990**

Power Controller—A new automatic power controller is designed to operate in conjunction with any standard universal testing machine. The Model TM-9 controller, an accessory of Marquardt's TM-6 universal testing machine, accurately controls high and rapidly rising temperatures on test specimens within 10 F in a range from room temperature to 6000 F. The TM-9 uses the electrical resistance of the material being tested to convert the electrical energy to heat. Only the specimen itself is heated, with absolute minimum thermal lag and maximum heating

efficiency. Standard ASTM specimens are heated in seconds to the required test temperature.

The Marquardt Corp. **3991**

Argon Analyzer—This specially designed instrument that analyzes traces of nitrogen impurities in argon is capable of full-scale calibration in the range of 0 to 20 ppm nitrogen in argon.

Mine Safety Appliances Co. **3992**

pH Recorder—An automatic pH-controller regulates, monitors, and records pH in any active fermentation or chemical process, at laboratory, pilot-plant, and production levels. It has its own indicating pH-meter and strip-chart recorder integrated with a peristaltic-action addition pump and a set of timers. The pH-instruments are standard Leeds & Northrup units and may be regulated at any preselected level throughout the entire acid-base range with an accuracy of ±0.1 pH.

New Brunswick Scientific Co., Inc. **3993**

Radiation Monitor—This new radiation monitor automatically guards an industrial or city water supply. The continuous water monitor system, Model WM-10, provides a choice of continuous native sampling, spot sampling, or automatic sampling of collected samples. Radiation levels are printed on permanent record tape directly in microcuries per milliliter $\times 10^{-9}$. Background is completely negated and does not appear on the record.

Nuclear Measurements Corp. **3994**

Gas Chromatography—The E-180 Actichromagraph, a simultaneous gas-chromatography and radioactivity measuring system, consists of a gas-liquid chromatograph and a special high-temperature ionization chamber for the measurement of tritium and carbon-14. This combination in a single instrument allows the convenient and complete separation of many classes of substances and the simultaneous measurement of the amounts of tagged radioactivity in each component. It is a powerful tool for research and classroom laboratories.

Radiation Equipment & Accessories Corp. **3995**

Particle Accelerator—A new 600-kv Model S particle accelerator is designed for use in basic research and applications in the field of nuclear physics and chemistry. Available in either a vertical or horizontal model, it offers highly stable continuous d-c outputs from 0 to 600 kv with infinite adjustment, capable of producing a wide range of particles and radiations (electrons, protons, neutrons, deuterons, X-rays, etc.).

SAMES (Société Anonyme de Machines Electrostatiques) **3996**

Dust-Free Cabinet—The new Model B Specialaire cabinet is an inexpensive dust-free illuminated work chamber for standard work benches for use in clean and contaminated areas. The unit is designed to provide high-dust arrestance for assembly research in ball bearings, semiconductors, and optical and precision instruments. The cabinet operates under a continuous flow of double-filtered air which prevents dust from entering the work area.

Specialties, Inc. **3997**

Hardness Testers—The Model H-5 microhardness tester now has a visual and an audible signal to follow the micromovement of an indenter into the part being tested. The instrument duplicates established dead-load hardness testers for rubber but uses micro proportions. Thin films of rubber, small molded pieces, O-rings, and experimental fragments can be evaluated in numbers that agree with the Shore hardness, A scale (ASTM Method D-676) and International Rubber Hardness Degrees (ASTM Method D-1415).

Testing Machines, Inc. **3998**

Vacuum Controller—A high-vacuum thermocouple controller, designated the TC-9, is a dual control unit for the automatic control of vacuum systems. The TC-9 is an automatic solid-state device with continuous "no-kick" indication even in the control region. It is designed for system protection, automatic process control, pressure monitoring, and for remote operation in inaccessible areas such as clean rooms.

Vacuum-Electronics Corp. **3999**

Material Grader—After years of research the Wheeler material grader has been developed to grade and test granular material. Two eccentric shafts of like eccentricity are mounted on the frame of the machine and are synchronized by two timing belt pulleys and a timing belt. A ¼-hp electric motor, having a speed of 1800 rpm, is mounted on a sliding base. It is equipped with a variable-speed drive pulley and connected to power with a drum-type reversible switch.

Delbert Wheeler **4000**

NEW LITERATURE

Textile Fibers—A free chart showing the resistances of all generic fibers to acids, alkalies, salts, solvents, and oxidizing agents is available. The chart indicates the concentration and temperature of the reagent and the extent to which the fiber or reagent resists chemical change and also defines the generic, man-made fibers and specifies the various trade names.

American Machine and Metals, Inc. Filtration Fabrics Div. **6548**

Scorch Testers—Two new scorch testers, both of which are easily and quickly set to any desired temperature between 250 and 440 F, are the SO-3A with 1¼ by 4 in. plates and the SO-5A with 5 by 5 in. plates. They are used for evaluating colorfastness and changes in physical properties of textiles due to wet and dry hot pressing. Closely controlled conditions of temperature and pressure ensure good reproducibility and repeatability of test results.

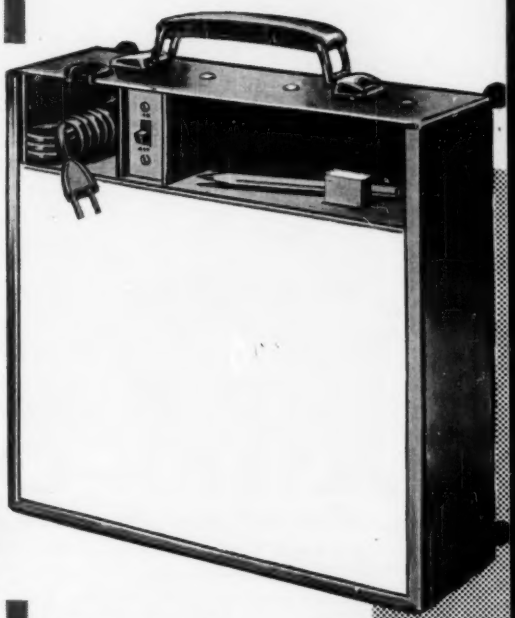
Atlas Electric Devices Co. **6549**

Strain Gages—A new line of weldable strain gages is described in *Product Data Sheet No. 4324*. The gages afford electrical stability and high linearity of response over a range of temperatures from cryogenic through 750 F, and offer temperature

(Continued on p. 1026)

Portable Cool... Glow Box

THE SCIENTIST'S LIGHT BOX

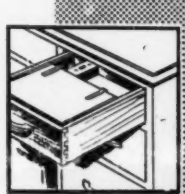


TILTS EASILY FOR TABLE-TOP USE

Model 12-12D for 8½ x 11" curves, charts, spectra, X-ray film, biological samples, etc. *Model 12-20E* for double size sheets, 11" x 18"

FITS STANDARD DESK DRAWER FOR STORAGE OR USE

Keep GLOW BOX in your desk drawer immediately available whenever you wish to examine, compare, or trace. It's so convenient!



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(*Continued from p. 1025*)

compensation to ±1 ppm per deg Fahr from 50 through 250 deg.
Baldwin-Lima-Hamilton Corp. 6550

Solution Pump—Illustrated, 2-page *Bulletin No. 794* describes the features, specifications, and operating principles of the new Beckman solution metering pump, which is designed for any application where small quantities of fluid must be precisely delivered. The new pump is available in four ranges: 0 to 2, 0 to 5, 0 to 10, or 0 to 20 ml per min.
Beckman Scientific and Process Instruments Div. 6551

Temperature Controller—An illustrated, 4-page, 2-color *Bulletin No. R-6000* describes the Blue M self-contained Power-O-Matic 60 saturable reactor package that operates without contacts, switches, moving parts, potentiometer sliders, etc. usually associated with on-off cycling-type control systems. Straight-line, stepless, switchless, infinitely proportional wattage control guaranteed.
Blue M Electric Co. 6552

Catalog—Sixteen-page laboratory *Catalog No. 61-9-76* lists over 200 items for analysis and testing.
Burrell Corp. 6553

Constant-Temperature Bath—*Bulletin B-10* describes a new improved constant-temperature bath for viscosity, density, refractive index, and general laboratory use. The unit is equipped with a thermoregulator that operates on a change of 0.004 C and in a range from room temperature to 212 F.
Cannon Instrument Co. 6554

High-Vacuum Valve—Complete information and details on the Cenco three-way high-vacuum valve are contained in an 8-page, illustrated *Booklet No. 328*. The three-way vacuum valve is designed to serve as a master control in high-vacuum systems using a diffusion pump and a mechanical pump. It offers minimum restrictions to gas flow and replaces the roughing, foreline, and high-vacuum valves now being used in many systems.
Central Scientific Co. 6555

Thermometer—A new 16-page general catalog, *Bulletin No. 09-100*, covers all Weston industrial, laboratory, Navy, and pocket types of bimetal thermometers that feature rugged all-metal construction, exceptional readability, and proved reliability. Available ranges, sizes, and types cover not only the usual industrial and laboratory uses, but are intended also for alarm and control systems, maximum-minimum indication, and other applications.
Daystrom, Inc., Weston Instruments Div. 6556

Laboratory Catalog—*Volume 29, No. 4* of "The Laboratory," published for 33 years, is now available in industrial, clinical, and Canadian editions. The current issue features the new "phantom dosimeter" developed by a Boston radiologist, Dr. M. S. Potsaid, and his research assistant, Dr. Goro Irie.
Fisher Scientific Co. 6557

Products List—This new edition of the *Foote Catalog* lists lithium chemicals, metal and minerals, electrolytic manganese, zirconium, welding-grade products, and steel addition agents for applications in the chemical, metallurgical, mining, ceramic, electronic, nuclear, and astronautic industries.
Foote Mineral Co. 6558

Dynamometer—A new technical *Bulletin J-10* shows photos and diagrams of the new aircraft wheel and brake-test dynamometer. How the system simulates a 250-mph landing at a given touchdown rate is explained. Also described are the system's three control functions of wheel speed versus time, wheel load versus time, and brake torque versus flywheel velocity.
Gilmore Industries, Inc. 6559

Laboratory Catalog—La items, *Volume 10, No. 3*, gives details on the macro accropet, omega chemicals, and laboratory equipment.
The Emil Greiner Co. 6560

Line Testing—A 6-page brochure, *Application Note No. 53*, describes a pulse-reflection technique for giving a direct reading of transmission-line characteristic impedance with a sampling oscilloscope. The application note briefly reviews transmission-line theory, and then discusses the equipment setup and types of reflections associated with the measurement.
Hewlett-Packard Co. 6561

Glass Catalog—A 294-page catalog of "Kimble Laboratory Glassware," *SP-75*, lists over 3000 items, many of them new items to Kimble, some of them exclusive, and many others in greater variety than listed in any other catalog from other manufacturers.
Kimble Glass Co. 6562

Ceramics—A catalog containing complete detailed information on space-age ceramic compositions such as alumina, magnesia, thoria, zirconia, and others also includes a complete list of sizes and prices for crucibles and tubing available from stock as well as data on custom ceramic items and a convenient application questionnaire.
Laboratory Equipment Corp. 6563

Filling Balance—A new line of low-weight-range filling balances that automatically weigh out granular or powdered substances is described in a new *Bulletin 102A*. The instruments operate in the range of 100 mg to 200 g, at speeds to 900 per hr. The system weighs out free-flowing powdered or granular materials, providing accuracies up to ±5 mg.
Mettler Instrument Corp. 6564

Testing Machine—The latest developments in physical testing and balancing machines are described and illustrated in an 8-page brochure, *Volume 13, No. 2*. Details are given on the 1,200,000-lb Super "L" universal testing machine, new

(*Continued on p. 1029*)

Atlas-Ometers

...Used all over the world

Give quick accurate answers to the deteriorating effect of sunlight, weathering, washing and wearing of materials. A few minutes, hours, or days in Atlas-Ometers equals years of normal use deterioration.

Indispensable for speed testing in product development and quality control in production. Exact standardized test programs can be repeated as frequently as required.

Used extensively in these industries:

Clothing makers	Automotive industry
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Electric manufacturing	Rugs and carpets
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U.S. Government	Paint, varnish, dry colors
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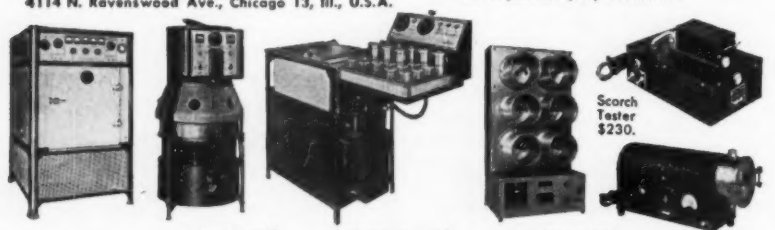
Complete manual on each machine on request

Atlas Electric Devices Company
4114 N. Ravenswood Ave., Chicago 13, Ill., U.S.A.

Weather testing translucent fiberglas for outdoor use in an Atlas Weather-Ometer at the Alsynite Company of America.



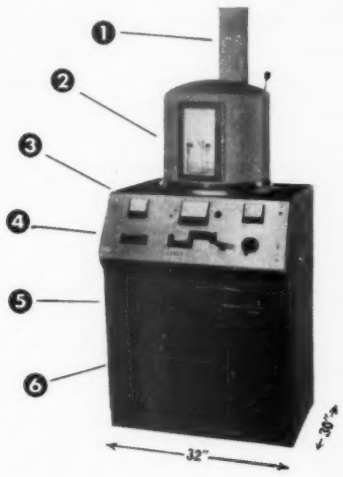
Weather-Ometer® $2755 up.
Fade-Ometer® $1350 up. Complete with supplies.
Launder-Ometer® $875 complete with accessories and supplies.
Random Tumble Pilling Tester $485 to $890.
Scorch Tester $230.
Accelerator® $485.

FOR FURTHER INFORMATION CIRCLE 1378 ON READER SERVICE CARD

Cenco's new compact

VACUUM SYSTEM

for thin-film coating, component testing and other research and limited production tasks requiring vacuum 2×10^{-6} mm of Hg



1 SAFETY HOIST spring-loaded hoist raises and lowers bell jar quickly and easily; locks solidly in any position.

2 ALUMINUM BELL JAR light-weight, implosion-proof—large window provides unimpeded view of the pump plate area.

3 TWO BUILT-IN ELECTRONIC VACUUM GAGES read directly from front panel—thermocouple gauge (1000 to 1 microns) connected into foreline discharge gage (20 to .001 micron) connected directly to pump plate.

4 THREE-WAY VALVE exclusive, single-lever valve permits immediate change-over and eliminates costly mistakes.

5 PUMPS a Cenco 14 Hyvac Pump backing a fast 6" oil diffusion pump for rapid bell jar evacuation.

6 POWER SUPPLIES the 19" pump plate contains 9 electrodes fed from either of two built-in power supplies—12 volt DC, 100 amps and 5000 volts AC, 30 ma, or conveniently fed from any external source.

The Cenco Vacuum System can evacuate to 0.1 micron in eight minutes using less than 1 pint of cooling water per minute. Input power required 30 amps at 115 volts. Dimensions, height 71", width 30", depth 32", only 960 sq. in. of floor space used. For further information contact the Cenco branch office nearest you, or write direct.

No. 94700, Cenco Vacuum System complete..... $3,950.00

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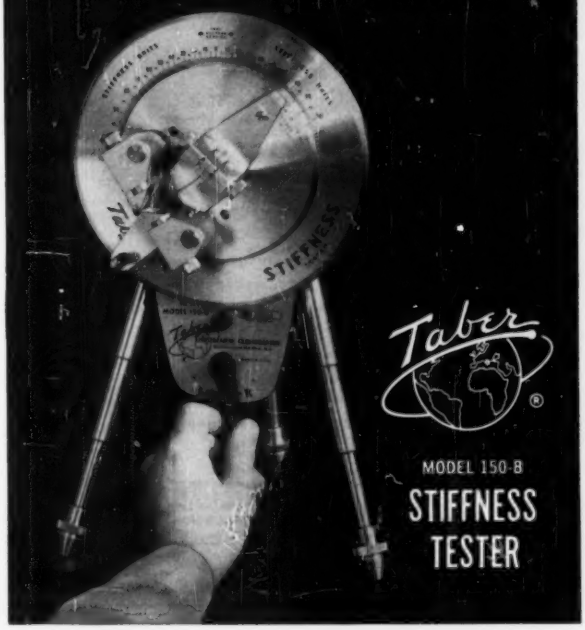
CIRCLE 1379 ON READER SERVICE CARD

stiffness and resilience of flexible materials measured quickly, accurately



This highly sensitive instrument will give you a quick, accurate measurement of material's *initial stiffness, basic stiffness,* and *resilience.* Nine ranges are provided for testing metals, plastics, paper, cardboard, wire, foil, and numerous other flexible materials up to ⅛" in thickness.

Because of its direct reading scale, the Taber stiffness tester can be operated by non-technical personnel. It features standardized test length, angle of deflection, graduation dial, and range weights to permit tests to be readily duplicated in laboratories throughout the world.

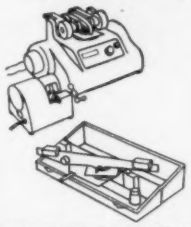
Detailed information on this device as well as other Taber testing instruments can be obtained by filling in and mailing the coupon below.

ABRASION TESTER MODEL 174

Measures wear life (or abrasion resistance) of metals, plastics, paints, rubber, textiles, linoleum, etc. under simulated conditions of actual use.

SHEAR/SCRATCH TESTER MODEL 203

Tests ability of plastics, plastic coatings and organic materials (up to ¼" thick) to resist digs, scrapes, etc. not classed as normal wear.



TABER INSTRUMENT CORP., SECTION 243,
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MAIL bulletin(s) describing
☐ Abraser ☐ Stiffness Tester ☐ Shear/Scratch Tester

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TENSILKUT®
TENSILGRIND

Precision Test Specimens
FROM ANY MATERIAL

TENSILKUT precision machines physical test specimens from hard .0005" stainless steel foil or .500" aluminum with machined edges free of cold working. Soft 1 mil plastic or ⅛" abrasive glass laminate are machined without heat distortion or edge deformation. A carbide cutter operating at high RPM achieves machining in a series of light rapid cuts.

TENSILGRIND precision grinds tungsten, molybdenum, and other refractory metals to RC 65 hardness. Specimens are precision ground by a series of light passes against a 7" diameter contoured grinding wheel. A solenoid controlled misting system insures cool grinding of the specimen edges.

Matched master templates guided by a tracer system allow unskilled personnel to machine or grind tensile, fatigue, flexure or other test specimens in minutes with configurations accurate to ±.0005".

TENSILKUT & TENSILGRIND available as table or floor models with motors from ½ to 2½ HP.

SIEBURG INDUSTRIES
INCORPORATED
Danbury Industrial Park, Danbury, Connecticut

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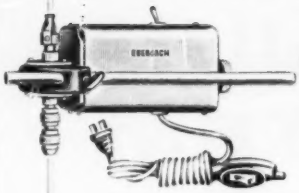
POWER-STIR® WITH GOVERNOR



Maintains Constant Speed Despite Voltage or Load Fluctuation

The Eberbach Corporation variable speed high torque stirrer is ideally suited to intermittent, medium duty, and has a speed range of 150 to 750 r.p.m. You will find abundant use for this stirrer where constant speed is required with changes of viscosity of substance stirred, for stirring example resin reactions, and many other laboratory jobs. Hollow spindle permits quick, smooth change of stirrer depth and removal of vessel. Governed Power-Stir Only.

Model 7105 – 150 to 750 r.p.m. $58
Model 7115 – 75 to 375 r.p.m. $58

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Colorimeters
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Special Types For Testing
Colors Petroleum Products

Glass Color Standards
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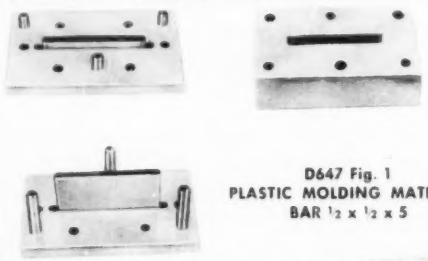
CIRCLE 1383 ON READER SERVICE CARD

When Ordering Steel Precision Molds
SPECIFY HOGGSON
Designed to ASTM Standards or YOUR Specifications



D647 Fig. 1
PLASTIC MOLDING MATERIAL
BAR ½ x ½ x 5

ANOTHER HOGGSON MOLD
Designed for a Specific Need

The D647, Fig. 1, Plastic Molding Material, Bar ½ x ½ x 5 was designed to answer a specific problem. Hoggson engineers are known throughout the world for reputable service in supplying manufacturers of rubber, plastic and synthetic products with precision molds and dies for test samples or actual production. Send your requirements for Hoggson's suggestions. Ask for literature.

HOGGSON & PETTIS MFG. CO.
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Pac. Coast: H. M. Royal, Inc., Downey, Calif.

CIRCLE 1384 ON READER SERVICE CARD

NEW LITERATURE

(*Continued from p. 1026*)

sheet metal ductility tester with *XY* recorder for plotting load versus depth of cup, high-speed automatic wire tester, new strain instrumentation including a unique separable extensometer, the latest Air-O-Brinell air-operated metal hardness tester, and the Vibrodyne balancer for checking vibration in production runs of fans for air conditioners as well as a variety of in-place balancing requirements.

Tinius Olsen Testing Machin Co. 6565

Laboratory Ware—New, *1962 Plastic Laboratory Ware Catalog* contains many new additions to the wide line of plastic beakers, carboys, bottles, tubing, funnels, containers, etc. The new catalog also contains a special insert which illustrates and describes the complete line of Palo Laboratory stirrers and accessories.

Palo Laboratory Supplies, Inc. 6566

Voltage Tester—A 4-page bulletin features a new line of high-voltage a-c test sets including the K-series high-capacity units with elaborate control circuits for maximum convenience and safety, for testing in accordance with ASTM Method D 149-59T.

Peschel Electronics, Inc. 6567

X-Ray Analysis—A new 4-page folder, titled *X-ray Analysis Solves Production Problems at General Refractories*, contains an article reprinted from a national engineering publication and deals with routine production control of chromic oxide and routine development work on iron oxide, silica, magnesia, and alumina. Also covered are qualitative and semiquantitative mineral research on mullite, corundum, and silica modifications. In addition, the author discusses mineral identification along with lattice constant determinations of solid solutions.

Philips Electronic Instruments 6568

Chromatography—Equipment for the the performance of thin-layer chromatography may now be obtained. The new adsorption method developed in Europe has gained rapid recognition in this country as a valuable analytical technique of wide application. A complete set of apparatus for preparing thin-layer plates and developing chromatograms on them is described and illustrated in the *RSCo Review*.

Research Specialties Co. 6569

Particle Monitoring—A programmable instrument for the continuous, unattended size-concentration analysis of airborne particulates is described in a new leaflet. The digital Model PC 200-A airborne particle monitor is illustrated and described as being available both with and without self-contained dilution facilities, essential for the monitoring of highly polluted environments.

Royco Instruments, Inc. 6570

Generators—New 8-page brochure describes electrostatic generators used in nuclear physics, insulation testing, electron microscopy and optics, X-ray generation, electrostatic precipitation, etc. Complete specifications for these high-voltage d-c power supplies are included, covering models ranging from 50 to 600-kv output.

SAMES (Société Anonyme de Machines Electrostatiques) 6571

Furnace—A new brochure describing a line of controlled-atmosphere furnaces gives details on 1200-C furnaces that find application in laboratory and production processes such as oxide-free brazing, degassing, ceramic and glass-to-metal, and seals.

Stewart Engineering Co. 6572

Proportional Controller—A 4-page illustrated brochure, *Instrument Section 53*, describes a new proportional controller, an instrument that contains several new functional design features for quick, more precise, dependable, and easier control of process conditions.

Thermo Electric Co., Inc. 6573

Geiger Tubes—A bulletin on the new line of low-voltage Geiger tubes, which operate at 480 v, is now available. The 4-page folder notes that the large-output pulses developed by the 480 series enable circuit simplification in instruments for detection and measurement control. The 480-series tubes are equally well suited for either pulse counting or current operations.

United States Radium Corp. 6574

MATERIALS

Stainless Steel—*How to Heat Treat Armco 17-4 PH Stainless Steel*, a new data folder produced in handy wall-chart form, is especially useful to heat treaters and other subcontractors working with this precipitation-hardening stainless steel grade. Six specific heat treatments are covered from condition A (as received from the mill), H 900, and H 925, to H 1150. Their effects on tensile and ultimate strength, Rockwell hardness levels, and 0.02 per cent elongation are listed.

Armco Steel Corp., Middletown, Ohio

Steel Corrosion—A new 60-page booklet, *The Role of Molybdenum and Copper in Corrosion Resistant Steels and Alloys*, contains numerous tables, charts, graphs, and photographs. It describes in detail the rapid development during the 1950's of corrosion-resistant steels based on the use of molybdenum, copper, and nickel, together with sufficient chromium to retain, in large measure, the resistance to oxidation provided in the familiar chromium and the austenitic chromium-nickel (18-8) types of stainless steel.

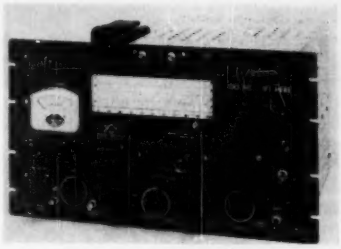
Climax Molybdenum Co., New York, N. Y.

Hydroxyacetic Acid—A new 24-page booklet describes general properties, chemical reactions, uses, and toxicology of this chemical.

E. I. du Pont de Nemours & Co., Wilmington, Del.

(*Continued on p. 1030*)

IMPROVED HIGH POWER PULSED OSCILLATOR, PG-650-C



The continued response of our clientele to the achievements of the PG-650-C model has led to further improvements. These include a ½ usec pulse with 3 cycles rise and fall, operation on C.W. and as a gated amplifier. This high powered pulsed oscillator has become standard equipment in leading laboratories in the United States and Europe for research in ultrasonics and nuclear magnetic resonance.

R.F. Output voltage (min) into 93 ohms ..... **0-300 p. to p. 0-600 Special order**

Pulse length—continuous ....**1½–13 usec**

Pulse droop **5%**

Noise output .....**Thermal noise from termination**

Harmonic output (mostly third) **10%**

R. F. Leakage .....**Negligible**

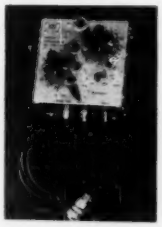
Calibrated delays ...**120, 1100, 11000 usec**

Gate Output available for intensifying and blanking purposes.

External modulation of r.f. oscillator

Special coils for coverage from .012 to 220 MC

PREAMPLIFIER, PA-620



This Preamplifier is a general purpose device for matching ultrasonic transducers and cables with capacities as high as 100 pfd between 5 and 65 MC, and to provide a limited amount of gain with a good signal to noise ratio. Two of the three stages have variable bandwidth as well as center frequencies. An additional feature is a comparer stage with separate gain control.

Specifications—

Input impedance	**93 to 3200 ohms**
Bandwidths	**0.5–17 MC**

Low noise cascode input with 6922 tube

FOR DETAILS AND PRICE LIST, WRITE TO:

ARENBERG ULTRASONIC LABORATORY, INC.

94 Green St., Jamaica Plain 30, Mass.

TEL. JAmaica 2-8640

CIRCLE 1385 ON READER SERVICE CARD

(*Continued from p. 1029*)

Fused Quartz—A new "ultrapure" fused quartz, the first to be made in the United States from domestic raw materials, has been announced. The new high-purity fused quartz will be particularly beneficial to the nation's research and development laboratories where, in many cases, even the smallest trace of impurities presents a problem. The semiconductor industry will also benefit from a much lower content of alumina and boron, previously a major problem in the manufacture of transistors. Because of its high purity, the new quartz has higher thermal resistance, enabling it to withstand high temperatures for longer periods of time. Tests show, for example, that the new material will deform at less than one half the rate of the former quartz when subjected to temperatures of 1200 deg C and higher. In addition, tubing and rod produced from the domestic source will devitrify much more slowly and remain more transparent at these high temperatures.

General Electric Co., Cleveland, Ohio

Ink—A new type of heat-resisting ink, called Okie Heat-Resisting Yellow, designed specifically for use as identification marks on steel, copper, brass, and on welding rods, is able to withstand temperatures up to 2500 F.

F. G. Okie, Inc., Ambler, Pa.

NEW MEMBERS

The following 61 members were elected from October 10 to November 9, 1961, making the total membership 10,839 . . . Welcome to ASTM. Names are arranged alphabetically, company members first then individuals. Your ASTM Year Book shows the areas covered by the respective Districts.

Chicago District

Bortz, Seymour A., engineer, Armour Research Foundation, Chicago, Ill.
Burns, James J., senior engineer, Northern Illinois Gas Co., Bellwood, Ill.
Geraci, Wayne A., research technician, Victor Manufacturing and Gasket Co., Chicago, Ill.
McFarlan, Tracy W., product manager, ultrasonics, Magnaflux Corp., Chicago, Ill.
Ulrich, Slack, supervisor, engineering standards and administration, Square D Co., Milwaukee, Wis.

Cleveland District

Benning, A. C., Inorganic Div., The Harshaw Chemical Co., Cleveland, Ohio.
Cobb, R. Virgil, research engineer, The Babcock & Wilcox Co., Research Center, Alliance, Ohio.

Detroit District

Chapel, Theron T., consultant, Port Huron, Mich.

* [A] denotes Associate Member.

Giszczak, Thaddeus, divisional chief metallurgist, General Foundry Div., General Motors Corp., Saginaw, Mich.

New England District

Steigerwald, R. M., staff manufacturing consultant, The Sippican Corp., Mattapoisett, Mass.
Zayne, J. Edward, section head, PVC Dept., The Borden Chemical Co., Division of The Borden Co., Leominster, Mass.

New York District

Blanchette, Joseph A., supervisor, polymer development, Research and Development Div., Mobil Chemical Co., Metuchen, N. J.
Grad, Peter P., chief chemical engineer, Rotron Manufacturing Co., Woodstock, N. Y.
Jarrold, J. T., eastern regional manager, Cain and Co., Great Neck, N. Y.
Jeff, William C., chief chemist, John L. Armitage and Co., Newark, N. J.
Moodie, William C., Jr., vice-president, engineering, Control Products, Inc., Hanover, N. J.
New York City Transit Authority, Charles F. Kane, division engineer, Brooklyn, N. Y.
Sawyer, R. Tom, directorate of engineering, U. S. Army Transportation Material Command, St. Louis, Mo.
Wakefield, Harold F., consultant, Upper Montclair, N. J.
Wilcoxson, Leslie S., metallurgist, Development and Research Div., The International Nickel Co., Inc., New York, N. Y.

Northern California District

MacIver, Bruce N., soils engineer, International Engineering Co., Inc., San Francisco, Calif.
Santa Clara, City of, Engineering Dept., Santa Clara, Calif.
Wagner, J. Forrest, director of laboratory, Dumont Manufacturing Corp., San Rafael, Calif.

Northwest District

Colby, Alan R., consulting engineer, Penticton, B. C., Canada.
U. S. Army Engineer District, Walla Walla, Corps of Engineers, H. B. Elder, resident engineer, John Day Lock and Dam, Walla Walla, Wash.
U. S. Army Engineer District, Walla Walla, Corps of Engineers, Leonard Estey, resident engineer, Ice Harbor Lock and Dam, Walla Walla, Wash.
U. S. Army Engineer District, Walla Walla, Corps of Engineers, E. C. Franzen, chief, Engineering Div., Walla Walla, Wash.

Ohio Valley District

Miller, Campbell E., partner, Miller, Wihry, & Lantz, Louisville, Ky.
Shober, Frederic R., assistant consultant, Reactor Metallurgy Div., Battelle Memorial Inst., Columbus, Ohio

Philadelphia District

Air Products and Chemicals, Inc., Library, Emmaus, Pa.

Pittsburgh District

Howe, Richard H., assistant soils engineer, Commonwealth of Pennsylvania, Depart-

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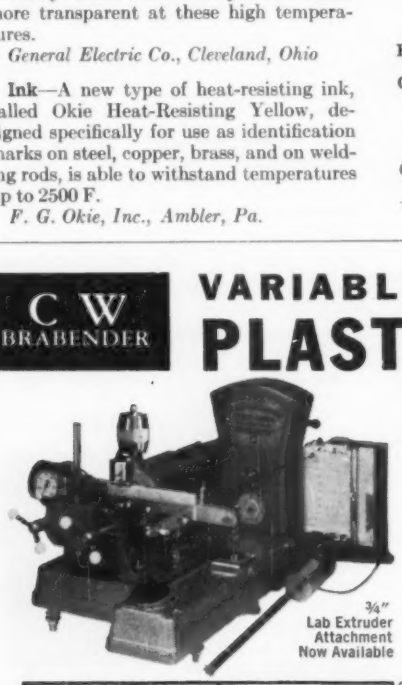

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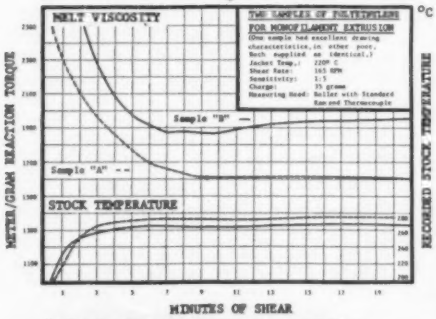

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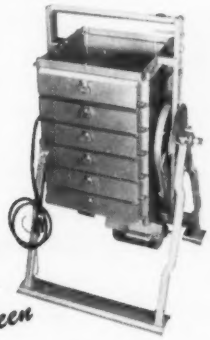

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ment of Highways, District 3-0, Montoursville, Pa.
Hunter, Charles J., chief metallurgical engineer, operations—steel, United States Steel Corp., Pittsburgh, Pa.

Southeast District

Low, Robert W., chief chemist, Biscayne Chemical Laboratories, Inc., Miami, Fla.
U. S. Army Engineer District, Jacksonville, Corps of Engineers, Jacksonville, Fla.

Southern California District

Moore, Thomas L., assistant manager of sales, Tubesales, Los Angeles, Calif.

Southwest District

Mayfield, R. S., chief engineer, Fenix & Scisson, Inc., Tulsa, Okla.
Rodenberger, Charles A., associate professor, Department of Aeronautical Engineering, Agricultural and Mechanical College of Texas, College Station, Tex.

Washington, D. C. District

Mangels-Herold Co., Inc., Rowell R. Dorsett, research director, Baltimore, Md.
Fisher, William D., supervisor of chemical laboratory, Sidney Blumenthal and Co., Inc., Rocky Mount, N. C.
Frier, Leonard, president, Maryland Electrical Testing Co., Inc., Baltimore, Md.
Hall, Laura T., research chemist, The Kendall Co., Charlotte, N. C.
U. S. Post Office Dept., C. Warren Hurley, chief, Postal Laboratory, Library, Washington, D. C.

Western New York—Ontario District

Ash, Arthur, technical service engineer, The Consolidated Mining and Smelting Company of Canada, Ltd., Toronto, Ont., Canada.

Outside Established Districts

Martin Testing Laboratory, Samuel Y. S. Taam, testing engineer, Honolulu, Hawaii.
Knight, George R., assistant professor, University of Alaska, College, Alaska.
Shumway, Ramon D., engineer of tests, Alaska Division of Highways, Juneau, Alaska.

Foreign

Fabrica Nacional de Canones, director, Trubia, Oviedo, Spain.
Petroleo Brasileiro S. A., Refinaria Landulpho Alves, Walmer Paixao, head, Laboratory Div., Salvador, Bahia, Brazil.
Yacimientos Petroliferos Fiscales, Marcelo Galart, general manager, Laboratorio Investigaciones (Biblioteca), Buenos Aires, Argentina.
Bowen, W. George, research and technical manager, TCF of Canada, Ltd., Cornwall, Ont., Canada.
Davis, William R., engineering manager, Montreal Engineering Co., Ltd., Montreal, P. Q., Canada.
Director of Standards, Ministry of Trade and Industry, P. Aldworth, director of standards, Trinidad, West Indies.
Giuliani, Francisco, civil and soils engineer, San Juan, Argentina.
Hanson, Owen Jerrold, works laboratory, Gillette Industries, Ltd., Isleworth, Middlesex, England. [A]*
John, Klaus, chief engineer, Internationale Versuchsanstalt fur Fels, Salzburg, Austria.
McQuhae, James L., product manager, gypsum, Western Gypsum Products, Ltd., Winnipeg, Man., Canada. [A]*
Metropolitan Corporation of Greater Winnipeg, The, Edward W. Frehs, chief building engineer, Winnipeg, Man., Canada.
Sison, Cesar L., project manager, Union Glass and Container Corp., Bo. Ugong, Pasig, Rizal, Philippines.
Sydney, The Council of the City of, R. D. Stevenson, city engineer, Sydney, N. S. W., Australia.
Trigg, Louis H., materials engineer, soils, Capitol Engineering Corp., Dillsbury, Pa.
Woodhouse, G. H., plant metallurgist, Manitoba Rolling Mills, Division of Dominion Bridge Co., Ltd., Winnipeg, Man., Canada.

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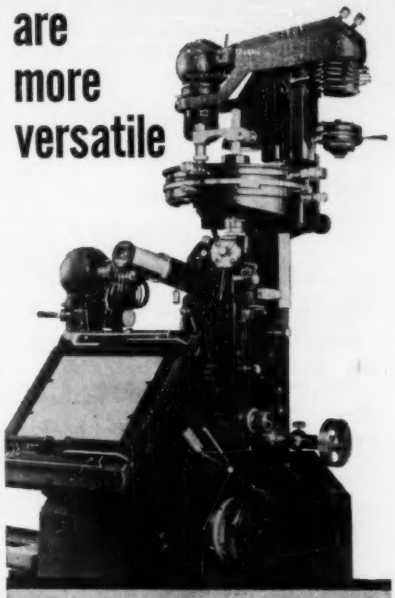

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GOVERNMENT STANDARDS CHANGES

THE FEDERAL Supply Service of the General Services Administration is charged with the responsibility for establishing specifications to be used by the Federal Government for Procurement of materials and supplies. The GSA issues an annual Index of Initiation of Federal Specifications Projects, and monthly supplements.

The following items appeared in Supplement 7 for September, 1961.

INITIATIONS

Title	Type of Action	Symbol or Number	FSC Class	Assigned Agency & Preparing Activity
Metal, Test Methods	New	Fed. Std. 151a		ARMY-ORD
Rubber, Sampling and Testing, Proposed Method 3061 International Rubber Hardness	Chg. No. 2	Fed. Std. 601		COM-NBS
Bolt, (Square Neck, Machine, Ribbed Neck, Finned Neck, Tee Head, Key Head) (Round Head)	Am. 1	FF-B-584b	5306	USAF
Boxes, Fiberboard, Corrugated, Triple Wall	Rev.	PPP-B-640b	8115	USAF
Cable and Wire, Power, Electrical, Nonmetallic-Sheathed	Rev.	J-C-0094a	6145	GSA-FSS
Cable and Wire, Power, Electrical (Service-Entrance and Service-Drop)	New	J-C-C0115	6145	GSA-FSS
Chipboard	New	UU-C-00282a	8135	GSA-FSS
Cloths, Abrasive, Aluminum Oxide and Silicon Carbide	Am. 1	P-C-451b	5350	NAVY-SHIPS
Cord, Electrical, Flexible, and Wire, Electrical, Fixture, (0 to 600 Volt Service)	Rev.	J-C-580a J-C-00580	6145	GSA-FSS
Enamel, Odorless, Alkyd, Interior High Gloss, White and Light Tints	Am. 1	TT-E-505a	8010	ARMY-CE
Insulation Board, Thermal	Int. Am. 1	HH-I-524	5640	GSA-FSS
Preparation for Delivery, Paint, Varnish, Lacquer and related items	Am. 1	TT-P-143a	8010	NAVY-SHIPS
Printing and Stationery Papers, Packaging and Packing for Domestic and Overseas Shipment	Rev.	PPP-P-25b	7530	GSA-FSS
Sealing Compound, Two Component, Elastomeric, Polymer Type, Cold Applied Concrete Paving	New	SS-S-00195	8030	ARMY-CE
Sodium Chromate Anhydrous, Technical	Rev.	O-S-588b	6810	ARMY-CMLC
Tongs, Laboratory	Rev.	GGG-T-549b GGG-T-00549a	6640	GSA-FSS
Towel, Bath, Cotton, Terry	Rev.	DDD-T-551e	7210	ARMY-QMC
1,1,1-Trichloroethane Technical Inhibited (Methyl Chloroform)	Int. Am. 1 Int. Am. 2	O-T-620a	6810	GSA-FSS
Webbing, Textile (Cotton Elastic)	Rev.	JJ-W-155b	8305	ARMY-QMC

INTERIM FEDERAL SPECIFICATIONS AND STANDARDS ISSUED

Title	Type of Action	Symbol or Number
Flame-Spread Properties of Materials	Rev.	Fed. Std. 00136a (COM-NBS)
Chipboard	New	UU-C-00282 (GSA-FSS)
Pipe, Asbestos-Cement, Under-drain, Perforated	Am. 1	SS-P-00340 (COM-PR)
Pipe, Bituminized-Fiber, Laminated Wall, Sewer, and Fittings for Same	Am. 1	SS-P-00345 (GSA-FSS)
1,1,1, Trichloroethane, Technical, Inhibited (Methyl Chloroform)	Am. 1	O-T-620a

PROMULGATIONS

Title	Type of Action	Symbol or Number
Cork Sheets (Gaskets, Sheets, and Strips) (Superseding HH-C-00576a (COM-NBS) & HH-C-576)	Rev.	HH-C-576b
Paint, Exterior, Chrome-Green, Ready-Mixed (Superseding TT-P-0071c (ARMY-CE) & TT-P-71b	Rev.	TT-P-71d
Paper, Carbon, Pencil	Am. 1	UU-P-154c

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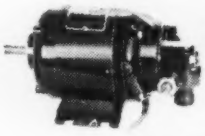

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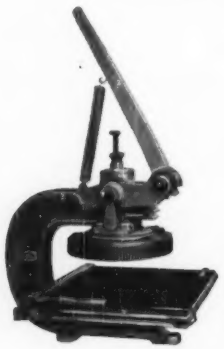

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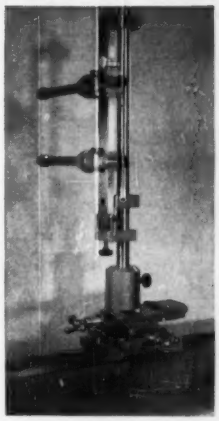

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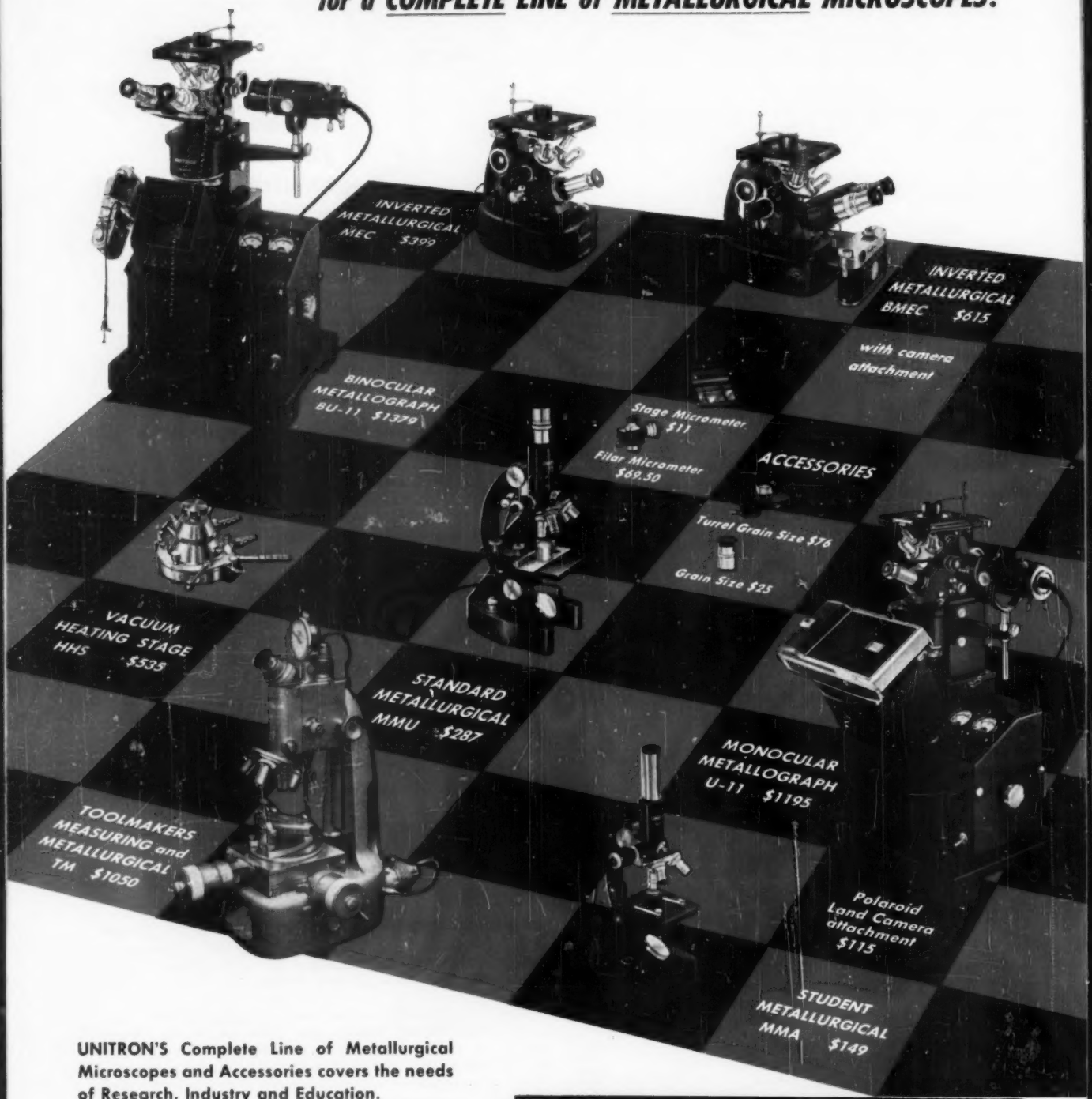

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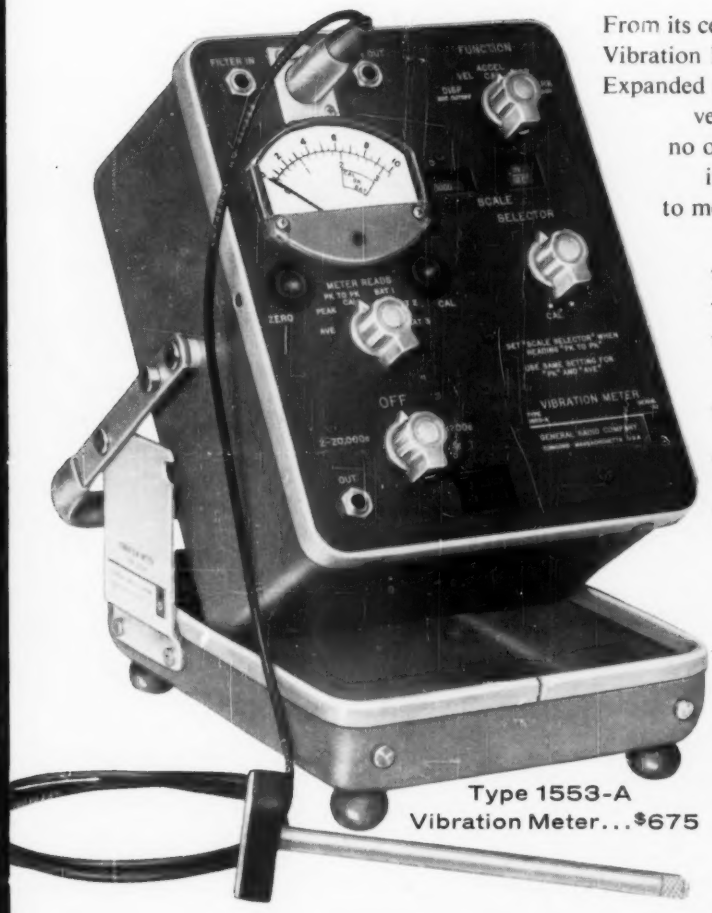

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FOR FURTHER INFORMATION CIRCLE 1394 ON READER SERVICE CARD

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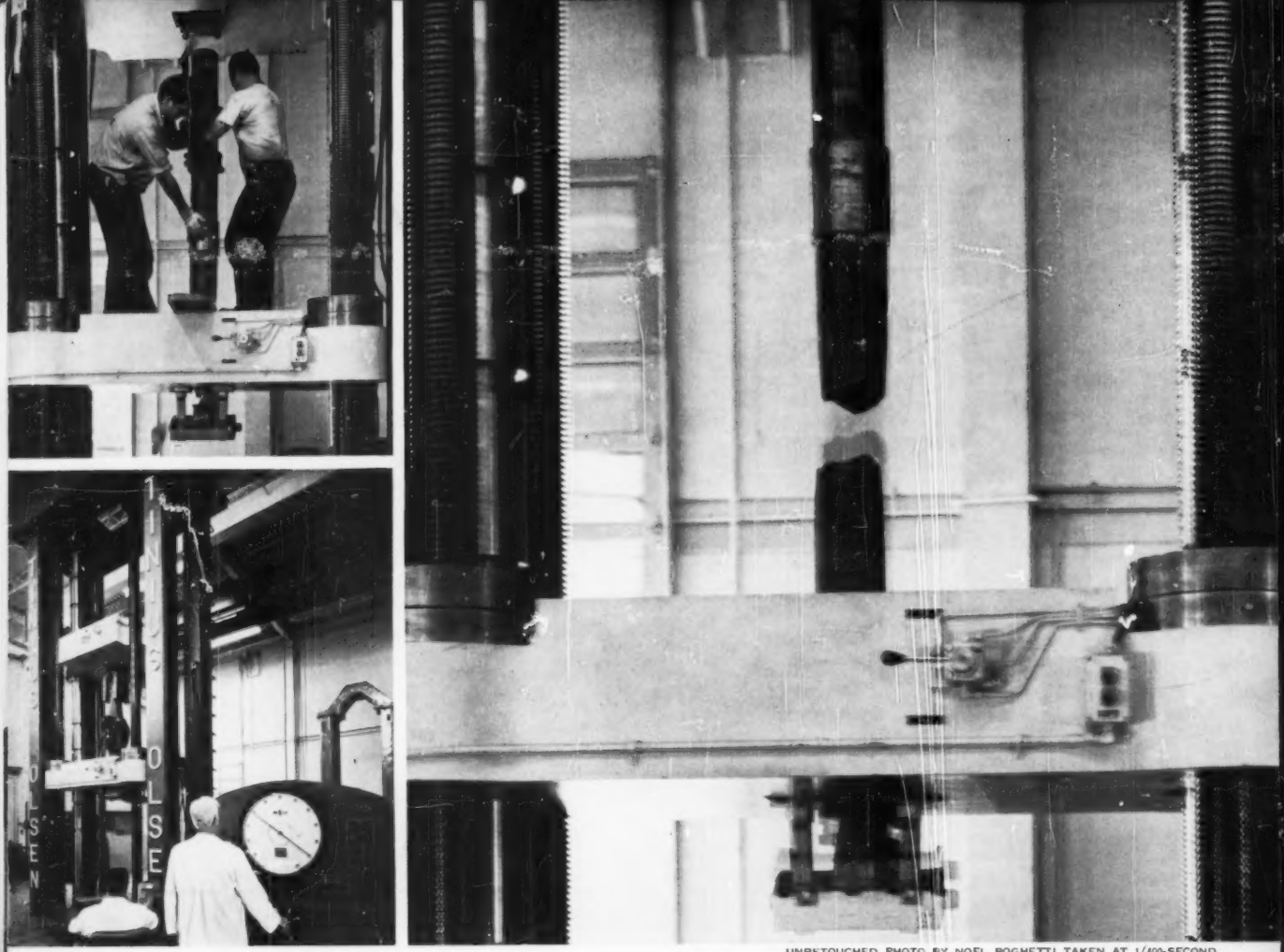

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FOR FURTHER INFORMATION CIRCLE 1395 ON READER SERVICE CARD

RESOLUT

INSTRUCTIONS Resolution is expr
film under specified conditions. Numerals
"T-shaped" groupings.

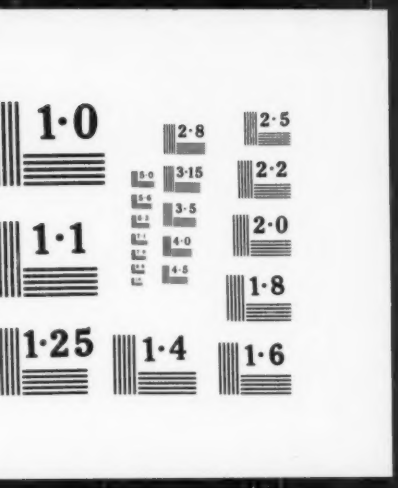
In microfilming, it is necessary to dete
chart by this value to find the number of l
ratio, the line above is 100 millimeters in le
into 100 gives the reduction ratio. Exam

Examine "T-shaped" line groupings in
lines recorded sharply and distinctly. Mult
in lines per millimeter. Example: 7.9 gro
not distinctly separated. Reduction ratio
rily. 10.0 x 5 = 50 lines per millimeter w
tions, maximum resolution is between 39.5

Resolution, as measured on the film, is
processing, and other factors. These rarel
exposure, lack of critical focus, and exposu

THE

TION CHART



100 MILLIMETERS

expressed in terms of the lines per millimeter recorded by a particular
erals in chart indicate the number of lines per millimeter in adjacent

determine the reduction ratio and multiply the number of lines in the
of lines recorded by the film. As an aid in determining the reduction
in length. Measuring this line in the film image and dividing the length
Example: the line is 20 mm. long in the film image, and 100/20 = 5.

gs in the film with microscope, and note the number adjacent to finest
Multiply this number by the reduction factor to obtain resolving power
group of lines is clearly recorded while lines in the 10.0 group are
atio is 5, and 7.9 x 5 = 39.5 lines per millimeter recorded satisfacto-
er which are not recorded satisfactorily. Under the particular condi-
39.5 and 50 lines per millimeter.

n, is a test of the entire photographic system, including lens, exposure,
rarely utilize maximum resolution of the film. Vibrations during
xposures yielding very dense negatives are to be avoided.

E END